JOURNAL

OF THE

FRANKLIN INSTITUTE

OF THE STATE OF PENNSYLVANIA,

FOR THE PROMOTION OF THE MECHANIC ARTS.

VOL. CXLI. MARCH, 1896. NO. 3

THE Franklin Institute is not responsible for the statements and opinions advanced by contributors to the *Journal.*

THE FRANKLIN INSTITUTE.

Annual Meeting, January 15, 1896.

MR. CHARLES BULLOCK, Vice-President, in the Chair.

THE MARSDEN CORN-PITH CELLULOSE.*

BY MR. LEWIS NIXON,
Late Naval Constructor, U. S. N.

The use of cellulose is so closely related to the subject of the buoyancy and stability of vessels at sea that it will doubtless prove interesting to explain, in a simple manner, some of the phenomena connected with the behavior of vessels under various conditions. Let us imagine a vessel which will ordinarily float upright in still water to be inclined by the action of some force. If, when the inclining force is removed, she tends to return to the upright position,

* [Marsden's Corn-Pith Cellulose is an entirely new American product. It is manufactured from the pith of the cornstalk or Indian maize into a granular form, and packed under pressure into the cofferdams of vessels; it acts as a perfect obturator, or water excluder, and is absolutely non-combustible.]

she is said to be stable. If she removes further away from the upright, she is said to be unstable.

A block resting on a table may be tilted over to a certain angle and still fall back to its original position, while, if it goes beyond this angle, it will fall over on its side. So we may incline a vessel and, within a certain angle, she will, when the inclining force ceases to act, return to the upright; but if pushed over beyond this angle, she will capsize. The angle to which she can be pushed and still retain stability is called the range of stability.

For present purposes we may define the metacenter of a vessel as a point of intersection of the line of action of the buoyancy when the vessel is upright, with the line of action of the buoyancy when the vessel is inclined through a small angle.

The statical stability of a vessel may be defined as the effort which she makes, when held steadily in an inclined position, to return to the upright position. In a stable vessel the metacenter must be above the center of gravity.

A vessel that has great metacentric height is said to be "stiff;" one that has small metacentric height, and that is easily inclined, is said to be "cranky." The metacentric height, then, may be taken as a measure of a vessel's stability for ordinary angles of roll. The range of stability—that is, the angle of inclination at which stability disappears—is as important as the metacentric height.

A vessel may have great metacentric height and a small range of stability; yet one having small metacentric height might return to the upright if turned upside-down.

The metacentric height of vessels varies greatly. Our monitors have metacentric heights of from 10 to 14 feet; the battleships from 3 to 4 feet; protected cruisers, 2 to 3 feet; tugs and small gunboats, from 1 to 2 feet. Generally speaking, it may be said that the greater the height of the vessel out of the water, the greater the range of stability, though deep draught is just as important, and we have had to sacrifice somewhat in range of stability in order to get our vessels on light draughts.

When a vessel goes to sea, the action of the waves makes

her roll. A vessel, like a pendulum, has, within limits, an approximately fixed time of oscillation; that is, she will roll through angles of 10° in about the same time that she will roll through angles of 5°. This being the case, we can imagine the periods between the successive impulses of the waves to be so timed that they will act just as a small child does in swinging a heavy man, by giving little pushes at the right time at each swing. In such a case we shall have very violent rolling, so great, in fact, as to roll the vessel over in case the range of stability is small. The friction of the water, however, reduces the angle of roll, generally, before it becomes so great as to become dangerous. Besides, the period is lengthened for great rolls, enough to sensibly decrease the danger of rolling over.

A great metacentric height brings the vessel up violently and quickly, making a short period; while the low metacentric height is associated with long period.

The combination which leads to heavy rolling is the synchronising of the half period of the waves with the period of rolling of the vessel. The largest wave observed in the North Atlantic was 2,750 feet long, and had a period of twenty-three seconds. However, ordinarily large storm waves are from 200 to 300 feet long, and have periods of from six to nine seconds. A vessel having a period of from three to four seconds, therefore, might often meet waves that would lead to violent rolling, so that she might have to cut across them transversely, or in some way destroy the synchronism. Very few men-of-war, however, have such short periods.

Gunboats are sometimes given comparatively great metacentric heights, but they are given bilge keels, or long projecting fins, to keep down the violent rolling. The reason that such gunboats are given such great metacentric heights is not, then, to make them better sea boats, for they usually have high sides and good ranges of stability, but because, if the best height were given them, they could not afford to lose any of it in battle.

This shows us why vessels, that would be easy in their movements at sea with a moderate metacentric height, giv-

ing them periods so long that most of the waves, instead of timing with the roll, would go by too fast to exert cumulative effects, are given great metacentric heights, leading to quick rolls, and making them poor gun platforms. This is, perhaps, right, in the main; but, naturally, the best way to proceed would be to determine on a proper metacentric height in designing a vessel, and then provide means for retaining it.

A hole in the side naturally lets in water, reducing the water-line area, upon which depends the metacentric height. The old wooden vessels were attacked by shell that made holes along the water-line, but the amount of water that entered was small, owing to the few hits, the swelling of the wood, and the fact that holes in wooden vessels could be comparatively easily plugged. A steel vessel under fire from modern ordnance is likely to receive a great many shots along the water-line, every one admitting water and causing a loss of metacentric height and range of stability. The first and most natural way of guarding against such water-line damage was to put a belt of armor all around the vessel, extending a few feet above and below the water-line. However, guns improved so rapidly that a thick enough belt could not be carried the whole length, so it was carried far enough to protect the machinery and give stability, even if the rest of the water-line plating should be destroyed, a thick under-water deck being carried from the ends of this thick belt to the extremities of the vessel.

Then again, in the protected cruiser, protection is given to the vitals of the vessel by a thick, curved, turtleback-shaped deck just above the water at the center of the vessel, curving down to below the water, where it meets the sides. Above this deck, to preserve the stability, numerous compartments are formed by water-tight metal bulkheads, so that only a small space may be flooded by one shot. However, there is a limit to subdivision, and few protected cruisers, with only the thick deck, could stand up long under a well-aimed fire from rapid-fire guns.

The use of some light substance along the slope of the protective deck to preserve the stability by displacing water

that might enter, in conjunction with the protective deck, to keep the shells from going into the machinery spaces and the magazines, was the next important step. So cofferdams were worked along this slope next to the water, in which were placed empty cans, cork, etc. The French improved upon this by originating the use of cellulose in these cofferdams, which, when fired into, swells up under the influence of water and prevents further inflow. The simplicity and efficiency of this method of protecting the stability of ships commended it to our Navy Department, and, after exhaustive trials, it was adopted for use along the slopes of the protective decks of our protected cruisers and battleships. Thus, in the *Columbia*, the *New York* and the *Olympia*, there are protective decks of ample strength to keep out the shells of any vessels they are likely to engage, while their stability is protected by belts of cellulose several feet thick along the edges of these decks. The English armored cruiser *Blake* has no such protection for her stability, and would not have the same chances as the above vessels of our Navy in a sustained engagement.

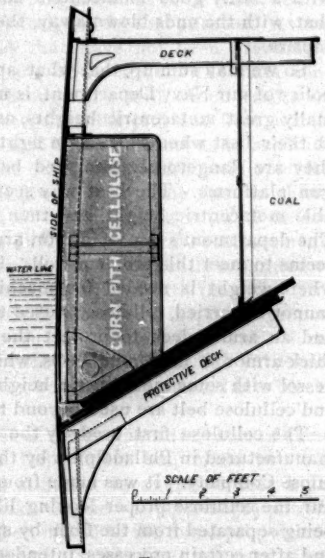


FIG. 1.

For keeping out water, a cellulose belt of 3 feet may be said to be about as efficient as a 6-inch belt of steel, so that we can protect our stability, when we have a good protective

deck back of it to protect the vitals, with 100 tons of cellulose, where we should require 1,000 tons of armor.

The *Inflexible*, of the English Navy, was given 8½ feet of metacentric height, leading, even with her great moment of inertia, to the small period of 5½ seconds. This was on account of the fear that the unarmored ends beyond the armor belt might be blown away. Such damage is improbable, and, beside the range of a central citadel vessel, even with a fairly good metacentric height, would be so small that, with the ends blown away, the vessel would probably capsize.

So we may sum up, that what appears to be the present policy of our Navy Department, is not to give vessels abnormally great metacentric heights, as they want them to be at their best when they begin fighting, and not wait until they are dangerously punished before they become good gun platforms. The best way seems to be to fix a reasonable metacentric height, and then take means to keep it. The department's use of armor, armor decks and cellulose seems to meet this problem well. In vessels of high speed, where weight is needed for machinery and an armor belt cannot be carried, cellulose is used to preserve the stability, and an armor deck to protect the vitals. In battleships, thick armor is used amidships, which will always keep the vessel with some metacentric height, and a protective deck and cellulose belt are used beyond the limits of this armor.

The cellulose first used by the Navy Department was manufactured in Philadelphia by the Franco-American Cellulose Company. It was made from the husks of the cocoanut, the cellulose proper looking like bits of ground cork, being separated from the fiber by specially built machines, and after certain processes, intended to prevent it from rotting and to render it incombustible, it was packed in the cofferdams, mixed with a certain amount of fiber to hold it together. The tests to which this cellulose was subjected were such as to produce an article superior to that used in France.

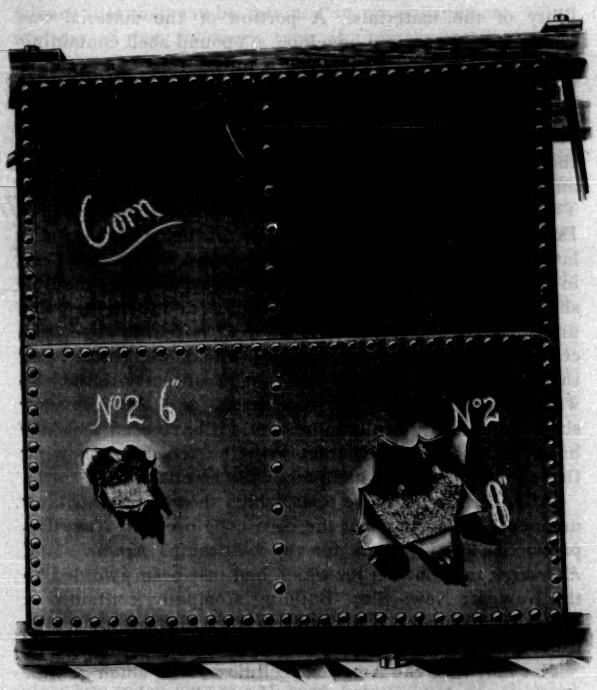
During the past year, the attention of the Navy Department was called to a new American product, manufactured

from the pith of cornstalks or Indian maize, which substance, it was claimed, possessed qualities superior to those of the cocoa cellulose. This substance is made under the patents of Mr. Mark W. Marsden, of Philadelphia. By this process, it is necessary to secure the largest cornstalks, well matured and harvested at the proper time, which must be dried by either natural or artificial means, and, when in proper condition, passed through a cutting-machine, which cuts the stalks into suitable lengths, so as to be easily fed in an attrition mill especially designed for that purpose. As the stalks are cut, the leaves that have not been previously stripped from the stalks are blown aside. The stalk containing the pith passes through the mill, which cracks or breaks the shell and disintegrates the pith and fiber, which enter a chamber so regulated by air currents as to separate the pith and fiber from the outer shell, which go in opposite directions. The pith and fiber, having some dust in them, are passed on through an air current with a suitable device attached to discharge the dust into a separate compartment, the pith and fiber being by this time sufficiently separated so as to give the proper percentage of fiber with the pith. The pith and fiber being perfectly clean, and in proper proportions, a chemical compound is combined in such form and manner as to render them fireproof, and the substance is then ready to pack into a box, or to be pressed into blocks ready for shipment.

In order to make a test of the comparative value of these two products, the Navy Department had made two cofferdams of steel plates, stiffened by angles, 6 feet high, 6 feet wide and 3 feet thick. In one was placed 832½ pounds of cocoa cellulose and fiber, mixed to the usual proportions corresponding to a density of 7·7 pounds to the cubic foot. The other cofferdam was packed with corn cellulose containing 702 pounds, corresponding to a density of 6·5 pounds per cubic foot. These cofferdams were sent to the Indian Head proving ground, and were fired at on June 10, 1895. The first shot was fired at the cocoa cofferdam. A 6-inch shot, having a velocity of 1,000 feet per second, was fired into the cocoa cellulose with a gun, at a distance of 314 feet.

The hole made at the point of entry was the diameter of the shot, and that at the point of exit at the rear of the cofferdam was an irregular, jagged hole, 7½ inches by 8½ inches. The center of the hole was 5 feet below the top of the cofferdam. The passage of the shot caused a quantity of cellulose to be projected to the front through the hole made, and about a quart to be thrown out to the rear. Water was now applied to the front of the cofferdam, the level being 5 feet above the hole. In ten minutes, the first drop of water appeared through the cofferdam through the hole. The flow increased gradually, and, in a few minutes, had become comparatively steady, running about 12 gallons in one-half hour. The flow of one-half gallon a minute then became approximately constant. In the meantime, the cofferdam containing the corn cellulose was fired at under similar conditions. Water was turned on as before, and left for one and one-half hours, during which time no water whatever appeared at the hole in the rear of the cofferdam; nor, at the end of the time, had the corn cellulose at the mouth of the hole in the rear become damp. The cofferdam containing cocoa cellulose was now fired at with a 250-pound 8-inch shell, at the same distance and with the same velocity as that of the 6-inch shell. The hole in the front was the size of the shell. In the rear, a rough hole was made about 12 x 9 inches. About a pint of cellulose was thrown out from the front hole, and about one-half gallon from the hole in the rear. The water was then turned on with a head of about 5 feet, as before. In twenty-five seconds, a few drops appeared at the hole in the rear, and about 12 gallons had passed through in thirty minutes. In about half an hour, the flow had settled down to a practical steady rate, or about one-half gallon per minute. Under similar conditions, an 8-inch projectile was now fired at the corn cofferdam, the conditions of firing being the same in both cases. The water was turned on, and, after waiting forty-five minutes, no water appeared at the hole in the rear of the cofferdam, nor was the corn at the rear damp. No water had appeared at the 6-inch hole which had previously been made, nor was it damp at the completion of the experiment.

With a view of determining the relative resistances of the materials to washing-out effect of waves on the exterior of a vessel, a stream of water was turned on from a steam fire pump. The nozzle was held at 12 feet from the 6-inch holes



Inboard View of Shot-Holes Corn-Pith Cofferdam.

in the front of the cofferdams, and directed full in these holes successively. At the end of 30 seconds, the material had been washed out in an elongated cone to a depth of about 18 inches from the surface in the case of the cocoa cellulose, and to a depth of 14 inches in the corn cellulose. It was

found by these experiments that there was no danger whatever of the cellulose material being washed out by the action of the sea, and thus failing to produce the obturating effects with either of the materials.

Tests were also made to show the relative non-combustibility of the materials. A portion of the material was placed loose in an iron envelope, a 3 pound shell containing $\frac{1}{10}$ pound of powder was exploded in its midst. A 1-pound bag of powder was exploded in a similar manner, in which case the cocoa cellulose ignited; the corn cellulose did not, but was greatly charred. Cocoa and corn cellulose were then packed separately in bags of a cubic foot capacity each, and two gallons of fresh water were poured into each box. The boxes were then placed in the basement of the Navy Department and examined from time to time. About a month later, it was found that the cocoa cellulose, which had been in contact with the iron, had turned black, and that the iron showed corrosion, except where painted, and there the paint under the action of the cellulose had softened. The corn cellulose showed that the painted portions were intact, and the paint was much firmer, and that in contact with the iron was only slightly black in some parts, and the iron very slightly corroded; hardly more would it have been the case had it simply been in contact with the moisture, showing that the corn cellulose had practically no effect.

After these exhaustive tests, which showed in a striking manner the superiority of the corn cellulose, the Navy Department's specifications for the battleships *Kentucky* and *Kearsarge*, the contract for which had just been awarded to the Newport News Ship Building Company, contained a clause requiring the cofferdams of these battleships to be packed with this substance.

Not only does the American cellulose show much greater absorptive and obturative powers than the cocoa cellulose, but it does not require to be packed to the same density. The cocoa cellulose is packed to $7\frac{1}{2}$ pounds per cubic foot, and the corn cellulose to $6\frac{1}{4}$ pounds. It is about $100 per ton cheaper than the cocoa cellulose, and this, with the lower density, makes it cost about two-thirds the amount per cubic

foot packed; the fact that it is much easier to pack still further reduces its cost.

With the perfect obturation which can be obtained with the corn cellulose, naval designers can settle upon the metacentric heights and other features of their designs with confidence that they can be retained in an engagement. Our cruisers of the *Baltimore* type, if they are provided with a cellulose belt, would be warranted in engaging many of the second-class ironclads of other powers; without it they are liable to be sunk by a well-directed machine gun fire. This product of American farms affords a cheap and ready means of vastly increasing the efficiency of our cruisers, and the unarmored sides of all our vessels should have these belts without delay. This discovery and application of cellulose is of as vital importance to our Navy as the development of harveyised armor and smokeless powder.

This follows from the fact that without adding very much to the cost of our vessels, we can greatly increase the efficiency of them all by making their sides automatically resist the inflow of water, and, as our cruisers carry heavier batteries than similar vessels of other nations, they would, when so protected, be able to give battle to ships far heavier than themselves.

COMMERCE AND DEEPWATERWAYS.*

By Prof. Lewis M. Haupt, Consulting Engineer.

[*Concluded from p. 97.*]

THE MISSISSIPPI RIVER.

On February 17, 1892, the steamer *Hoxie* took a "tow," consisting of six freight barges and one coal barge, containing 8,566 tons, down the Mississippi. This load, if placed in 30-ton cars would have required 285, or, allowing 40 feet to the car, the train would have covered, without engines, 2⅛ miles of track. The average freight rates from St. Louis via New Orleans by water to Liverpool are 14 cents per bushel, as compared with 21 cents overland, via

* A lecture delivered before the Franklin Institute, December 13, 1895.

New York. The saving of this 7 cents per bushel, if applied to the grain shipments from New Orleans, for 1892, would represent nearly $500,000 saved on this one staple.

Although St. Louis is 1,355 miles from the Gulf by river, and only 946 by rail from New York, yet it will be seen that the water route can compete with the rail rate and still have a large margin. With an open deep-water port on the West Gulf Coast, but 720 miles distant, it can even then ship by rail to that port in competition with Eastern shipments; for if the ocean rate be taken at only $\frac{1}{10}$ that by rail, the 226 miles difference in favor of the Gulf would be equivalent to 2,260 miles at sea.

From the trans-Mississippi district it is estimated that at least an average of 500 miles may be saved in the overland haul by shipping from the Gulf instead of from the Atlantic ports, and a very simple calculation will give an idea of what this means to the United States.

If the railroad charge be taken at only 6 mills per ton mile, which is much below the average, a saving of 500 miles each way, or 1,000 miles in the round trip, means $6 per ton, or 18 cents per bushel on wheat, or its equivalent. For export alone (one way only) it is 9 cents, or at 22 bushels per acre, $2 would be added to the profits of every acre of wheat per annum. Thus the 1,000,000 square miles tributary to the West Gulf Coast, containing 640,000,000 acres, would be increased in value annually by $1,380,000,000 if they could be made to produce wheat or its equivalent—a value altogether beyond our ability to comprehend.

This will perhaps illustrate why the Government has made such persistent, vigorous efforts to secure deep water at Galveston, and why, now that the jetties are extended over the bar, recourse had been had to hydraulic dredging with the results previously mentioned.*

BRUGES,† BELGIUM.

Turning now to one of the oldest seaports of the continent, it will be found that the town of Bruges, in Belgium, is full of suggestion.

*For a history of this work, see *Franklin Institute Journal* of October, 1891. "The Galveston Harbor Problem."

†Page 135 of Jean's "Waterways and Water Transport," London, 1890.

"This Venice of the North lay formerly near the sea on a gulf of considerable depth, and was easily accessible to the largest ships. So capacious was her port that in the year 1213, Philip Augustus, at the head of 1,700 sail, closed in it with the allied English and Flemish fleets. So long as her communication with the sea remained open, Bruges maintained her commercial power; but the successive accumulations of clay in the Lwyn, and in the outer ports, caused the lamentable state of things which followed. In the latter part of the thirteenth century a canal was cut of such dimensions as to give access to vessels of from 400 to 500 tons, the largest then afloat. This so stimulated commerce that for fifty years, from 1420 to 1470, Bruges was the mart of the world, and her fortune reached its climax. But shortly before the discovery of America, the deposits in the Lwyn again interrupted commerce. Charles the Bold caused the polder of the Lwartegat to be opened, hoping to scour out the channel, but without success. Twelve years later the large draft vessels ceased to appear, and the canal which had maintained the marvellous prosperity of the old city was buried under the accumulated silt from the sea, and Bruges was condemned to a long decline. In 1622, the opening of a canal to Ostend was determined upon, and twenty years later one was dug from Bruges to Nieuport and thence to Dunkerque. In 1646, this latter port was surrendered to France and the Flemings were obliged to turn their attention to Ostend. The dimensions of the canal were greatly increased, and in 1717 the *Compagnie des Indes* was organised at Ostend, to increase the commercial movements. It was very successful at first, and would have restored to Bruges her former circulation and life, had not the Treaty of Paris, of 1727, inspired by the jealousy of Holland and England, suspended for seven years the grant of the company, and later, forbidden all commercial intercourse between the Austrian Netherlands and the Indies. Four years later the treaty of Vienna, of 1731, expressly stipulated 'that all commerce and navigation from the Austrian Netherlands to the East Indies, as also that all commerce and navigation from the East Indies to the Austrian Netherlands, shall cease forever.'"

In 1783, Joseph II, wishing to end the subjection of his provinces, undertook to build a canal to the sea, exclusively on Flemish ground, but failed in the attempt. It was only after the Netherlands had been joined to France that Napoleon ordered a canal to be dug from Bruges to Damme, but it was not completed before the fall of the empire. In 1829, King William resumed the scheme of Napoleon, and decided to push the canal to Breskens; but just before beginning, the revolution of 1830 again put an end to the hopes of Bruges and the people were in despair, when, in 1877, M. Ade Mære Limander proposed a ship canal to the sea at Ostend, 7½ miles, with moles and harbor works. The dimensions were: width at bottom, 65 feet; at top water surface, 204 feet; depth, 23 feet; slopes, ⅓. It was supplied with water from the sea. This canal has cost over $3,000,000, and has abundantly proven the wisdom of its projectors.

During the past four centuries, therefore, four distinct attempts have been made to restore communication between Bruges and the sea, three of which were unsuccessful, but not so much in consequence of the physical difficulties to be overcome as through political complications and national jealousies—factors which are still potent in restricting the construction and improvement of the waterways of the world.

A contract is now being executed to build a new seaport at "Heyst on the North Sea, at the mouth of the canal that will make Bruges once more a seaport large enough to hold fifteen of the largest trans-Atlantic steamers. The breakwater will stretch more than two miles out to sea. The port will cost $5,400,000, and $2,400,000 will be spent on the canal."

The experience of Antwerp is well known, but it may be well to add it to this record as an evidence of the benefits resulting from low taxes on vessels. Up to 1863 the Dutch Government taxed all vessels using the Scheldt to such an extent as to make it burdensome. A treaty was concluded that year by which, in consideration of certain specific payments made by the various countries whose ships used the river, that the dues should be renounced. Since then the

trade of Antwerp has advanced by leaps and bounds. Between 1862 and 1887, the imports increased by 335 per cent., and the exports by more than 500 per cent. The general transit trade also increased 400 per cent., and the tonnage of vessels entering the ports advanced by about 600 per cent.

EXPERIENCE WITH THE SINGLE JETTY SYSTEM.

Bilbao, Spain.—Another remarkable instance resulting from the removal of an ocean bar is to be seen in the case of Bilbao, on the north coast of Spain, in the Bay of Biscay. Here a single curved breakwatèr was built by M. Churruca, to regulate the discharge of the river, and it was expected to secure a low-water depth of 20 or 22 feet. This work was completed about 1888, and the results were very satisfactory; the commerce increased immediately from 1,400,000 to 4,600,000 tons annually.

Greytown.—Another illustration of the efficacy of single jetties for removing bars is to be found in the case of the entrance to the harbor at Greytown, at the mouth of the Nicaragua Canal. Here a single but straight jetty converted a dry sand bar into a 15-foot channel, while at the mouth of the Columbia the single jetty has secured a depth of 30 feet over the once dangerous bar obstructing its entrance. The second jetty originally designed to be built has been found to be unnecessary.

One Jetty vs. Two.—The policy of maritime engineers the world over has been to construct jetties in pairs so as to concentrate, if possible, the ebb scour of the tidal waters over the outer bars; but experience has shown this to be at best a slow, expensive and unsatisfactory procedure, and of late years there has been considerable discussion as to the relative merits of single *vs.* twin jetties for ocean bar removal. Advocates of the submerged, convergent jetties in pairs, as designed for such cases as Charleston, Galveston, etc., have abandoned their theories, after practical tests, as untenable, and have substituted the high and compact stone jetties in pairs, aided by hydraulic dredging on the bar, requiring continual expense for maintenance.

Thus far, the single jetty, when placed originally on the

side of the channel from whence comes the littoral drift, as required by the physical conditions of the entrance, has invariably been more or less successful.

Aransas Pass, Texas.—The latest application of this principle is now being made at Aransas Pass, Texas, the strategic commercial port of our Mediterranean Sea. Here a contract was let, last July, for the construction of a single reaction breakwater, to be built on the plans proposed by the writer, upon private capital, advanced by Messrs. Alex. Brown & Sons, of Baltimore, and, by the time the foundation mat was laid and covered with rock to a depth of only 2 feet and length of 1,250 feet, there was an increase in depth, on the channel side on the outer slope of the bar, of 7 feet, also a deepening of 6 feet beyond the outer end of the work, and a general breaking up on the crest of the bar, without any progression seaward. In reporting these facts after a few months' work, Mr. Brewster Cameron, the general manager, to whose energy this enterprise is chiefly due, wrote, on November 2d: "The results thus far have exceeded our expectations and surpassed your predictions, and have more than vindicated the wisdom of yourself and associates in reversing the order of harbor works and beginning the improvement on the outer slope of the bar."

A letter from Baltimore, of date November 22d, states that: "We fail to find any place with less than 13 feet of water on the bar," although the first portion of the breakwater was not completed to high water, and had not been extended as far landward as the crest of the bar. The prevailing depth, as reported by the U. S. Coast and Geodetic Survey of 1891, was $7\frac{3}{4}$ to 8 feet, so that this would indicate an increase of at least 4 feet, in a few months, entirely across the bar, even before the superstructure of the breakwater had reached its crest, a result which, it need hardly be added, is entirely unprecedented in the history of bar removal, by either natural or mechanical agencies. The measure of this result will be better understood by comparison with the harbor works at Dublin, concerning which it was reported:*

* *Vide Franklin Institute Journal*, April, 1888, "Jetties for Improving Estuaries."

There are few, if any, cases of bar entrance to any harbor being increased in depth like that of Dublin, viz.: about 7 feet in thirty years, and great credit is due those who designed, as well as those who executed, works which have achieved so important a result. The improvement of Dublin harbor ranks second to none. There is no other example, so far as the author is aware, of the construction of an artificial estuary for scouring purposes which has proved so successful."

The great North Wall at Dublin, to which all the beneficial results are ascribed, was built between 1819 and 1825, a period of six years. For a distance of 5,600 feet it rises to a height of 6 feet above high water, and is 30 feet wide on top; thence it slopes to the bottom, which it reaches at a distance of 9,000 feet from shore.

The rate of scour is shown from the following statement:

Date.	*Depth at Low Water.* ft. in.	*Interval in Years.*	*Increase in Depth* ft. in.	*Rate of Inc. Per Annum.* in.	*Depth at High Water.* ft. in.	*Mean Rise of Tide.* ft.
1822 . .	6 3	—	—	—	19 3	13
1828 . .	9 6	6	3 3	6·5	22 6	13
1833 . .	10 6	5	1 0	2·4	23 6	13
1856 . .	13 0	23	2 6	1·81	26 0	13
1873 . .	16 0	17	3 0	2·1	29 0	13
Totals,		51	9 9	2·3		

from which it appears that the total increase of depth is but 9¾ feet, the average scour being only 2·3 inches per year for over fifty years' time, with a tidal oscillation of 13 feet. The total volume of water estimated to pass through the jetties at each tide is 24,000,000 tons, or 31,600,000 cubic yards.

This slow but constant improvement in depth is attributable to the fact that a gap was left in the North Wall some 600 feet in length, to admit the tide more freely, thus producing a preponderance of ebb over flood movements in its exit through the entrance, 1,000 feet wide at low water.

The money expended at Aransas Pass, Texas, by private parties in 1869, and subsequently by the Government, has served its purpose in indicating the probable solution of the

perplexing question of how best to secure a deep water entrance on the west gulf coast. A few quotations from this experience will, therefore, be quite pertinent. The reports of the chief of engineers for 1887 say, in substance:*

"Works were begun in 1880, and suspended in 1885. The Pass was moving southward at the rate of 260 feet per year. The depth over the bar varied. It was 9 feet in 1852, 7½ feet in 1868, 9½ feet in 1871, 7 feet in 1875, and 7 feet in 1878;" average, 8 feet, which was also the depth in 1892, when an official survey was made. The object of the Government work was: (1) "to stop the southward movement of the Pass;" (2) to deepen the channel over the bar at the entrance to 12 feet, and (3) to stop the erosion of the bounding islands by wind.

Results.—"The work designed to deepen the channel over the bar, consisting of a single jetty, constructed upon the south side of the entrance, has had no important effect upon the bar, and is in a dilapidated condition. The channel depth over the bar is now 8½ feet, and the channel crosses the jetty. The works designed to stop the erosion of the surface of the islands by wind, consisting of sand fences and plantations of salt cedars, have disappeared, and left no traces behind." The officer in charge, who had been but recently assigned to this district, therefore recommended a change of plan, consisting of two jetties, 2,000 feet apart at their outer ends, extending in parallel lines to the 20-foot curve, and rising to 5 feet above mean low water. "They are expected to secure and maintain a channel depth of not less than 20 feet." "The original estimated cost of this work, as here revised, is $2,052,543.72, and the amount actually expended is $383,618.02."

From the above it appears that this latter sum was spent with a resulting depth of only 8½ feet, or practically no improvement, while the present effort has produced an unprecedented movement of material at a cost not exceeding $113,000 spent to date of survey. It is, of course, too early to predict the final results from this single breakwater, and

* August 6, 1887, Report Chief of Engineers.

these are only stated for what they may be worth, but they are so unusual as to merit attention.

It is not our purpose at this time to enter into the principles and operation of this design of breakwater, but only to call attention to it, as opening up a new and apparently remarkably cheap and rapid method of removing ocean bars, and of improving our commercial waterways, by the application of the reaction induced by concave dikes and jetties properly oriented with reference to the axis of the ebb and flood currents and littoral drift.

It may happen that by this treatment of the ocean bars obstructing our alluvial shores, they may be so readily and cheaply removed as greatly to stimulate the industries dependent upon ocean commerce, and also increase the demands already existing for a more vigorous and systematic deepening of our internal channels by rivers and canals.

Ten years have passed since the Interstate Committee reported, yet comparatively little progress has been made in the emancipation of the waters, upon which they laid great stress.

After a searching investigation, that committee found as follows:

"There are several important internal improvements which must soon be undertaken by the general Government if the United States are to keep step with the leading nations of the world in the grand march of progress. * * * The great European powers appear to be engaged in an earnest and determined contest for commercial supremacy. In this contest we cannot afford to be sidetracked, but must engage in the race for cheaper transportation with all possible energy and vigor.

"The cheapest mode of transportation known is by water. The railroads have accomplished wonders, but no railroad can successfully compete with a free and unobstructed water route, so far as the cost of carriage is concerned. Therefore, to secure the blessings of cheap transportation, and to hold our place among the nations of the earth, we must develop our natural waterways to their

fullest capacity, and give the benefits of lake, river and canal communication to the people of all the States, so far as practicable. * * *

"The chief defects of the present water routes of the country, as a whole, are that they are too long for successful competition with the railroads, and that they are too isolated for successful co-operation. The obvious and only possible remedy for these defects is to *shorten* them and *unite* them (by canals). * * * By thus shortening the existing lines of water communication and rendering them navigable for steam vessels of large carrying capacity, the cost of freight service could be reduced to the lowest possible minimum, not only between a few great centers of trade, but between interior points in almost every part of the country.

"A comprehensive system of internal improvements would develop to their utmost extent the inexhaustible resources of the United States; would give new life and healthy activity to trade; would put bread in the mouths of thousands of men now seeking employment without success; would avert the dangers to be apprehended from railroad combinations to control the commerce of the country, and would secure rates of transportation that would always enable the surplus products of the nation to find a profitable market.

"The manifest destiny of our country points unerringly to this *emancipation of the waters*, as its next great work, a destiny not of war, but of beneficence and peace, to which the heart of the nation turns as spontaneously and resistlessly as the waters of its great river flow to the Gulf."

To bring about this consummation so devoutly to be wished, it is fundamental that we should fully appreciate our present possibilities and the defects of the system which has proven so inadequate to provide speedy relief. By way of comparison as to our internal waterways, it may be stated that in the United States:

	Miles.
The length of our ordinary canals was reported in 1890 to be	2,099·1
The length of maritime or river canals	179·4
The length of canalised rivers	1,070·2
Giving a total of only	3,348·7

for an area of 3,019,140 square miles; while France, with her territory of only 204,092 square miles (or nearly 60,000 square miles less than Texas), has 7,703 miles of improved river and canal navigation. This is at the rate of one mile to 27 square miles of area, while in the United States it is 1 to 1,000, very nearly.

The movement on the French waterways, which in 1880 reached 1,247,095,000 ton-miles, was increased to 2,117,400,000 in 1891, while the price of freights dropped to $\frac{1}{10}$ cent, or even less for long distances. This is largely due to the unification of the gauge, so as to admit boats of 300 tons capacity, one of which is, therefore, equivalent to about ten of our largest freight cars.

The French Government has expended many hundreds of millions on these public works, and it is stated by their political economists that the canals, even when free, pay 5 per cent. per annum in economising the national wealth.

The work is under the supervision of the Corps des Ponts et Chaussées, a permanent organization of civil engineers, organized for this express purpose.

On this point the late Col. Wm. E. Merrill, of the United States Corps of Engineers, who built the Davis Island Dam, reported:

"As a final conclusion from the study of French and American experience in inland navigation, it may be stated that modern practice is decidedly in favor of the development of all the natural waterways of a country to their full capacity, and of the creation of as many artificial waterways as the financial resources and physical conditions of the country will permit; that such waterways should be absolutely free of toll; that they should be under the control of a permanent body of engineers wholly disconnected with politics; and, finally, that the expenditures necessary to secure these results are profitable to the commonwealth, even though the profits do not appear in direct returns to the treasury."

These conclusions are unquestionably sound and commendable, yet the existing system of temporary assignments of officers in charge is not calculated to produce the

best results. Our own port of Philadelphia has, for example, in the past twenty years been in charge of no less than eight officers, an average of two and one-half years each, with the result that the bars controlling the entrance, having depths of 20 feet and covering a length of 5 or more miles, are still in a state of nature, and our commerce has been largely superseded by that of our sister ports, New York, Boston and Baltimore, while ocean rates are so high, in consequence of the withdrawal of our largest steamers, that it is said it pays better to send our foreign freight to New York or Boston than to ship from the home port. It is to be expected, however, that the recent awakening of our citizens to the importance of providing suitable terminal facilities along the Delaware frontage, the removal of the islands, which has been rapidly prosecuted under the resident Government official, and the liberal appropriations of our municipal authorities, will measurably stimulate our foreign commerce and increase to some extent the transshipments from rail to water at this point. But it is likewise important that greater facilities should be provided for the passage and handling of our coastwise commerce along the safe interior lines, which may be provided by the enlargement of our existing tributary canals and the permanent removal of the bars at the head of the bay, which control the entrance to the river.

These are works of great moment to the welfare of our commonwealth. They should commend themselves to the personal sympathy and support of every one of its citizens, who should use every legitimate effort for the *accomplishment* of this laudable purpose.

The lecture was closed with views of the river Tyne, the coal engorgement at Pittsburgh, the Delaware River and Bay, the harbors of Philadelphia and Antwerp, and views along the canals, with the hydraulic dredging plants in use on the Pacific Coast for improving channels and reclamation of lands.

On a New Kind of Rays.*

By W. C. Röntgen.

(1) A discharge from a large induction coil is passed through a Hittorf's vacuum tube, or through a well-exhausted Crookes' or Lenard's tube. The tube is surrounded by a fairly close-fitting shield of black paper; it is then possible to see, in a completely darkened room, that paper covered on one side with barium platino-cyanide lights up with brilliant fluorescence when brought into the neighborhood of the tube, whether the painted side or the other be turned toward the tube. The fluorescence is still visible at 2 meters distance. It is easy to show that the origin of the fluorescence lies within the vacuum tube.

(2) It is seen, therefore, that some agent is capable of penetrating black cardboard, which is quite opaque to ultra-violet light, sunlight, or arc-light. It is, therefore, of interest to investigate how far other bodies can be penetrated by the same agent. It is readily shown that all bodies possess this same transparency, but in very varying degrees. For example, paper is very transparent; the fluorescent screen will light up when placed behind a book of 1,000 pages; printer's ink offers no marked resistance. Similarly, the fluorescence shows behind two packs of cards; a single card does not visibly diminish the brilliancy of the light. So, again, a single thickness of tinfoil hardly casts a shadow on the screen; several have to be superposed to produce a marked effect. Thick blocks of wood are still transparent. Boards of pine 2 or 3 centimeters thick absorb only very little. A piece of sheet aluminum, 15 millimeters thick, still allowed the X-rays (as I will call the rays, for the sake of brevity) to pass, but greatly reduced the fluorescence.

---

* Translated by Arthur Stanton from the *Sitzungsberichte der Würzburger Physik-medic. Gesellschaft*, 1895.—*London Nature.*

Glass plates of similar thickness behave similarly; lead glass is, however, much more opaque than glass free from lead. Ebonite several centimeters thick is transparent. If the hand be held before the fluorescent screen, the shadow shows the bones darkly, with only faint outlines of the surrounding tissues.

Water and several other fluids are very transparent. Hydrogen is not markedly more permeable than air. Plates of copper, silver, lead, gold and platinum also allow the rays to pass, but only when the metal is thin. Platinum ·2 millimeters thick allows some rays to pass; silver and copper are more transparent. Lead 1·5 millimeters thick is practically opaque. If a square rod of wood 20 millimeters in the side be painted on one face with white lead, it casts little shadow when it is so turned that the painted face is parallel to the X-rays, but a strong shadow if the rays have to pass through the painted side. The salts of the metals, either solid or in solution, behave generally as the metals themselves.

(3) The preceding experiments lead to the conclusion that the density of the bodies is the property whose variation mainly affects their permeability, at least no other property seems so marked in this connection. But that the density alone does not determine the transparency is shown by an experiment wherein plates of similar thickness of Iceland spar, glass, aluminum and quartz were employed as screens. Then the Iceland spar showed itself much less transparent than the other bodies, though of approximately the same density. I have not remarked any strong fluorescence of Iceland spar compared with glass (see below, No. 4.)

(4) Increasing thickness increases the hindrance offered to the rays by all bodies. A picture has been impressed on a photographic plate of a number of superposed layers of tinfoil, like steps, presenting thus a regularly increasing thickness. This is to be submitted to photometric processes when a suitable instrument is available.

(5) Pieces of platinum, lead, zinc and aluminum foil were so arranged as to produce the same weakening of the

effect. The annexed table shows the relative thickness and density of the equivalent sheets of metal.

	Thickness. Millimeters.	*Relative Thickness.*	*Density.*
Platinum . . .	·018	1	21·5
Lead	·050	3	11·3
Zinc	·100	6	7·1
Aluminum . .	3·500	200	2·6

From these values it is clear that in no case can we obtain the transparency of a body from the product of its density and thickness. The transparency increases much more rapidly than the product decreases.

(6) The fluorescence of barium platino-cyanide is not the only noticeable action of the X-rays. It is to be observed that other bodies exhibit fluorescence, *e. g.*, calcium sulphide, uranium glass, Iceland spar, rock salt, etc.

Of special interest in this connection is the fact that photographic dry plates are sensitive to the X-rays. It is thus possible to exhibit the phenomena so as to exclude the danger of error. I have thus confirmed many observations originally made by eye observation with the fluorescent screen. Here the power of the X-rays to pass through wood or cardboard becomes useful. The photographic plate can be exposed to the action without removal of the shutter of the dark slide or other protecting case, so that the experiment need not be conducted in darkness. Manifestly, unexposed plates must not be left in their box near the vacuum tube.

It seems now questionable whether the impression on the plate is a direct effect of the X-rays, or a secondary result induced by the fluorescence of the material of the plate. Films can receive the impression as well as ordinary dry plates.

I have not been able to show experimentally that the X-rays give rise to any calorific effects. These, however, may be assumed, for the phenomena of fluorescence show that the X-rays are capable of transformation. It is also certain that all the X-rays falling on a body do not leave it as such.

The retina of the eye is quite insensitive to these rays; the eye placed close to the apparatus sees nothing. It is clear from the experiments that this is not due to want of permeability on the part of the structures of the eye.

(7) After my experiments on the transparency of increasing thicknesses of different media, I proceeded to investigate whether the X-rays could be deflected by a prism. Investigations with water and carbon bisulphide in mica prisms of 30° showed no deviation either on the photographic or the fluorescent plate. For comparison, light rays were allowed to fall on the prism as the apparatus was set up for the experiment. They were deviated 10 millimeters and 20 millimeters, respectively, in the case of the two prisms.

With prisms of ebonite and aluminum, I have obtained images on the photographic plate, which point to a possible deviation. It is, however, uncertain, and at most would point to a refractive index 1·05. No deviation can be observed by means of the fluorescent screen. Investigations with the heavier metals have not as yet led to any result, because of their small transparency and the consequent enfeebling of the transmitted rays.

On account of the importance of the question, it is desirable to try in other ways whether the X-rays are susceptible of refraction. Finely powdered bodies allow, in thick layers, but little of the incident light to pass through, in consequence of refraction and reflection. In the case of the X-rays, however, such layers of powder are, for equal masses of substance, equally transparent with the coherent solid itself. Hence, we cannot conclude any regular reflection or refraction of the X-rays. The research was conducted by the aid of finely powdered rock salt, fine electrolytic silver powder and zinc dust, already many times employed in chemical work. In all these cases the result, whether by the fluorescent screen or the photographic method, indicated no difference in transparency between the powder and the coherent solid.

It is, hence, obvious that lenses cannot be looked upon as capable of concentrating the X-rays; in effect, both an ebonite and a glass lens of large size prove to be without

action. The shadow photograph of a round rod is darker in the middle than at the edge; the image of a cylinder filled with a body more transparent than its walls exhibits the middle brighter than the edge.

(8) The preceding experiments, and others which I pass over, point to the rays being incapable of regular reflection. It is, however, well to detail an observation which at first sight seemed to lead to an opposite conclusion.

I exposed a plate, protected by a black paper sheath, to the X-rays, so that the glass side lay next to the vacuum tube. The sensitive film was partly covered with star-shaped pieces of platinum, lead, zinc and aluminum. On the developed negative, the star-shaped impression showed dark under platinum, lead, and, more markedly, under zinc; the aluminum gave no image. It seems, therefore, that these three metals can reflect the X-rays; as, however, another explanation is possible, I repeated the experiment with this only difference, that a film of thin aluminum foil was interposed between the sensitive film and the metal stars. Such an aluminum plate is opaque to ultra-violet rays, but transparent to X-rays. In the result the images appeared as before, this pointing still to the existence of reflection at metal surfaces.

If one considers this observation in connection with others, namely, on the transparency of powders, and on the state of the surface not being effective in altering the passage of the X-rays through a body, it leads to the probable conclusion that regular reflection does not exist, but that bodies behave to the X-rays as turbid media to light.

Since I have obtained no evidence of refraction at the surface of different media, it seems probable that the X-rays move with the same velocity in all bodies, and in a medium which penetrates everything, and in which the molecules of bodies are embedded. The molecules obstruct the X-rays, the more effectively as the density of the body concerned is greater.

(9) It seemed possible that the geometrical arrangement of the molecules might affect the action of a body upon the X-rays, so that, for example, Iceland spar might exhibit dif-

ferent phenomena according to the relation of the surface of the plate to the axis of the crystal. Experiments with quartz and Iceland spar on this point lead to a negative result.

(10) It is known that Lenard, in his investigations on cathode rays, has shown that they belong to the ether, and can pass through all bodies. Concerning the X-rays, the same may be said.

In his latest work, Lenard has investigated the absorption coefficients of various bodies for the cathode rays, including air at atmospheric pressure, which gives 4·10, 3·40, 3·10 for 1 centimeter, according to the degree of exhaustion of the gas in discharge tube. To judge from the nature of the discharge, I have worked at about the same pressure, but occasionally at greater or smaller pressures. I find, using a Weber's photometer, that the intensity of the fluorescent light varies nearly as the inverse square of the distance between screen and discharge tube. This result is obtained from three very consistent sets of observations at distances of 100 and 200 millimeters. Hence, air absorbs the X-rays much less than the cathode rays. This result is in complete agreement with the previously described result, that the fluorescence of the screen can be still observed at 2 meters from the vacuum tube. In general, other bodies behave like air; they are more transparent for the X-rays than for the cathode rays.

(11) A further distinction, and a noteworthy one, results from the action of a magnet. I have not succeeded in observing any deviation of the X-rays even in very strong magnetic fields.

The deviation of cathode rays by the magnet is one of their peculiar characteristics; it has been observed by Hertz and Lenard, that several kinds of cathode rays exist, which differ by their power of exciting phosphorescence, their susceptibility of absorption, and their deviation by the magnet; but a notable deviation has been observed in all cases which have yet been investigated, and I think that such deviation affords a characteristic not to be set aside lightly.

(12) As the result of many researches, it appears that the place of most brilliant phosphorescence of the walls of the discharge tube is the chief seat whence the X-rays originate and spread in all directions; that is, the X-rays proceed from the front where the cathode rays strike the glass. If one deviates the cathode rays within the tube by means of a magnet, it is seen that the X-rays proceed from a new point, *i. e.*, again from the end of the cathode rays.

Also, for this reason the X-rays, which are not deflected by a magnet, cannot be regarded as cathode rays, which have passed through the glass; for that passage cannot, according to Lenard, be the cause of the different deflection

FIG. 1.

of the rays. Hence, I conclude that the X-rays are not identical with the cathode rays, but are produced from the cathode rays at the glass surface of the tube.

(13) The rays are generated not only in glass. I have obtained them in an apparatus closed by an aluminum plate 2 millimeters thick. I purpose later to investigate the behavior of other substances.

(14) The justification of the term "rays," applied to the phenomena, lies partly in the regular shadow pictures produced by the interposition of a more or less permeable body between the source and a photographic plate or fluorescent screen.

I have observed and photographed many such shadow pictures. Thus, I have an outline of part of a door covered with lead paint; the image was produced by placing the discharge tube on one side of the door and the sensitive plate on the other. I have also a shadow of the bones of the hand (*Fig. 1*), of a wire wound upon a bobbin, of a set of weights in a box, of a compass card and needle completely enclosed in a metal case (*Fig. 2*), of a piece of metal where the X-rays show the want of homogeneity, and of other things.

For the rectilinear propagation of the rays, I have a pin-

FIG. 2.

hole photograph of the discharge apparatus covered with black paper. It is faint, but unmistakable.

(15) I have sought for interference effects of the X-rays, but possibly, in consequence of their small intensity, without result.

(16) Researches to investigate whether electrostatic forces act on the X-rays are begun but not yet concluded.

(17) If one asks what, then, are these X-rays; since they are not cathode rays, one might suppose, from their power of exciting fluorescence and chemical action, that they are due to ultra-violet light. In opposition to this view a weighty set of considerations presents itself. If X-rays be, indeed,

ultra-violet light, then that light must possess the following properties:

(*a*) It is not refracted in passing from air into water, carbon bisulphide, aluminum, rock salt, glass or zinc.

(*b*) It is incapable of regular reflection at the surfaces of the above bodies.

(*c*) It cannot be polarised by any ordinary polarising media.

(*d*) The absorption by various bodies must depend chiefly on their density.

That is to say, these ultra-violet rays must behave quite differently from the visible, infra-red, and hitherto known ultra-violet rays.

These things appear so unlikely that I have sought for another hypothesis.

A kind of relationship between the new rays and light rays appears to exist; at least the formation of shadows, fluorescence, and the production of chemical action point in this direction. Now, it has been known for a long time that, besides the transverse vibrations which account for the phenomena of light, it is possible that longitudinal vibrations should exist in the ether, and, according to the view of some physicists, must exist. It is granted that their existence has not yet been made clear, and their properties are not experimentally demonstrated. Should not the new rays be ascribed to longitudinal waves in the ether?

I must confess that I have, in the course of this research, made myself more and more familiar with this thought, and venture to put the opinion forward, while I am quite conscious that the hypothesis advanced still requires a more solid foundation.

CHEMICAL SECTION.

Stated Meeting, December 17, 1895.

DR. WM. C. DAY, President, in the Chair.

MODERN THEORIES OF ELECTROLYSIS.

BY DR. JOSEPH W. RICHARDS, of Lehigh University.

All science is based on the observation of phenomena, which supplies us with facts. The orderly arrangement of these facts, their tabulation and classification, give us *descriptive science*. The natural questioning of the human mind as to the why and wherefore of these facts, and especially of the observed relations between groups of facts, gives us *theoretical science*.

Regarding the observed relations between phenomena, a probable guess as to the wherefore of these relations is an *hypothesis*. When the hypothesis agrees with almost all the known phenomena, explains them naturally and satisfactorily—and, especially, if it be substantiated by rendering predictions which are afterwards verified by observed new facts—it constitutes a *theory*. When the theory is so completely proven that no exceptions can be cited to its operation, it then rises to the dignity of a *natural law*.

The subject in hand to-night does not, therefore, directly deal with the facts of electrolysis, or the verified laws of electrolysis, but with the attempts to explain the observed facts and the proven laws by postulating relations which have not yet been fully proven. It will be necessary, however, to review, in a concise manner, those facts and laws, in order to reach a better understanding of the theory.

We may class all bodies, provisionally, as conductors and non-conductors of electricity, although the division is not an exact one. Non-conductors require a very high potential to pass an electric current through them. No trace of conduction appears until this very high potential is reached; then the material suddenly gives way, so to

speak, as if the electric force had literally torn a path through it.

Conductors are substances which conduct electricity to some degree, at the lowest potentials.

We can distinguish two kinds of conductivity—metallic and electrolytic. A metallic conductor transmits electricity without exhibiting any chemical or physical change, except that it becomes heated by the passage of the current. The conductivity of metallic conductors decreases with rising temperature, and *vice versa*, and in such a ratio as to make the assumption plausible that, at the absolute zero (— 273° C.), their resistance becomes zero. Thus, the electric conductivity of aluminium at 0° C. is 50 (silver being 100), while at — 220° C. it conducts nine times better than at 0°; so that, compared with silver at 0° C., its conductivity would be in the ratio of 450 to 100. At — 273° C., the conductivity of metallic conductors is infinite; there is no resistance to the passage of the current.

Electrolytic conductors transmit electricity; but, in doing so, suffer a chemical change. They are necessarily compound bodies, and they are separated into two constituents, which appear, respectively, at the electrodes, *i. e.*, the points where the metallic conductors bringing the current come in contact with the electrolytic conductor, or electrolyte. A direct current causes these constituents (*ions*) to gather on the electrodes, and, if the current be suddenly interrupted and the wires connected with a galvanometer, a counter current traveling in the reverse direction from the original one will be observed, caused, no doubt, by recombination of the separated ions. We might compare this to an elastic recoil. Metallic conductors show no trace of such spring-back or recoil. The conductivity of electrolytes increases with rising temperature; in fact, most of them are to be regarded as practically non-conductors in the solid state at ordinary temperatures, and only become conductors when rendered liquid by a solvent or by fusion.

We have, therefore, three very striking points of difference between metallic and electrolytic conduction. The difference between an electrolytic conductor of high resist-

ance and a weak dielectric (non-conductor) is, however, not so clear; but time will not permit a discussion of this point this evening.

Amongst the non-conductors we may catalogue:

Fluorine, chlorine, bromine, iodine, oxygen, sulphur, if pure, and their compounds with hydrogen when these are pure liquids.

Ammonia and its compounds conduct badly, or not at all. Metallic organic compounds, *e. g.*, zinc methyl, are non-conductors.

Hydrocyanic acid, carbon-bisulphide, benzol, ether, toluol, naphthaline and many organic liquids are insulators, at least for a tension of 140 volts.

Many substances are non-conductors in the solid state, and conductors when melted. Faraday, in his experimental researches, catalogues the following salts as of this class:

Oxides of potassium, lead, antimony, bismuth; chlorides of potassium, sodium, barium, strontium, calcium, magnesium, manganese, zinc, copper, lead, tin, antimony, silver.

Iodides of potassium, zinc, lead, tin, mercury; fluoride, cyanide, sulpho-cyanide and chlorate of potassium.

Nitrates of potassium, sodium, barium, strontium, lead, copper, antimony.

Sulphates of sodium, lead, mercury.

Phosphates of sodium, potassium, calcium, copper, lead.

Carbonates of potassium, sodium.

Borates of sodium, lead, tin.

Chromates of potassium, lead.

Sulphides of potassium, antimony.

Kohlrausch makes a wider generalisation, and states that the chlorides, bromides, iodides, fluorides, oxides and sulphides of lithium, sodium, potassium, rubidium, cæsium, beryllium, magnesium, calcium, strontium, barium, aluminium, cerium, thorium, and the rare earths, are all, when in the *molten state*, good electrolytic conductors. Their aqueous solutions are also good electrolytes; but as the metals decompose water, their hydrates are usually deposited

by secondary action. The corresponding salts of copper, silver, gold, zinc, mercury and cadmium behave similarly, being good conductors when melted, while the metal *can* be obtained from the aqueous solution. On the other hand, Kohlrausch classes the following as non-conductors, when molten:

> Sulphur, phosphorus, sulphur iodide, stannic iodide and chloride, arsenious chloride and sulphide, boric acid, sugar, wax, shellac, stearin, spermaceti, camphor.

Faraday thought he could draw the conclusion from his experiments that a compound, to be capable of electrolysis, must contain an equal number of atoms of a different kind in its molecule, and that those which contain more atoms of one substance than of another in their molecule are non-conductors. This has proved to be a very imperfect generalisation, having since been disproved experimentally by exceptions in both directions, while modern chemistry has repudiated many of the formulæ on which he based his hypothesis.

Kohlrausch made a generalisation which modern research has so far not subverted, but rather confirmed: "No simple, unmixed substance is an electrolyte at ordinary temperatures, though many are when heated." The corollary of this is that "all bodies showing electrolytic conductivity at ordinary temperatures are mixtures of simple substances." Pure water was long thought to be an exception to this rule; but it has recently been shown by this investigator that the freer the water is from impurities the poorer is its conductivity, and he has prepared water whose conductivity at 18° C. is only 0·04, that of mercury being 10,000,000,000. The specific conductivity in reciprocal ohms in this case would be only 0·000000042, or the resistance of a column 1 centimeter square by 1 centimeter long, 23,809,523 ohms. It was not certain that this water was absolutely pure, so that Kohlrausch's generalisation, in the light of our present knowledge, still stands as practically true.

Faraday was the first to place on a firm foundation our knowledge of the quantitative relation between the strength of an electric current (its quantity) and its power to effect

chemical decomposition. Starting with the idea that chemically equivalent quantities of the elements represent equivalent quantities of chemical combining energy, Faraday's greatest discovery was that "equal quantities of the electric current do an equal amount of chemical work; that is, set free from combination, chemically equivalent quantities of the elements." There is no need here to expatiate on this well-known and well-established law. The momentous inference from it was, that a certain definite quantity of electricity appears to associate itself with chemically equivalent weights of the elements, and that each valence, or bond of chemical combining power possessed by an element, appears to require a definite amount of electricity for its dissociation. This law has already done good service in chemistry in helping to fix the combining power of elements whose valence was in doubt.

However, the *quantity* of an electric current is only one factor in the expression for its energy. Quantity multiplied by intensity equals energy. Ampères multiplied by volts equals work. Faraday knew that there was an intensity factor associated with the decomposition of a compound, but he lacked the grand work of Thomsen in chemical energy, and of Joule in electrical mechanics, which would have enabled him to penetrate the mazes of this part of the subject.

Since Faraday's time, Thomsen, Berthelot and the numerous workers in thermo-chemistry, have measured accurately the heat set free in chemical combinations, and have thus given us thermal equivalents for the energy of chemical affinity. Joule, on the other hand, has given us the quantitative relation between thermal, mechanical and electrical energy. Thanks to this new science, based on the conversion and conservation of energy, we are now able to understand the exact relations between chemical and electrical energy. We know the chemical energy of a combination expressed in heat energy. We can convert this into electrical energy by Joule's constants. But as we already know, by Faraday's law, the *quantity* of the electric current taking part in the decomposition of the substance, we have

the data from which to calculate the intensity, or potential, which it must have—since energy divided by quantity equals intensity.

For example:

1 ampère × 1 volt = 1 watt = 0·24 gram-caloric per second.
1 ampère sets free from water, 0·00001035 gram of hydrogen per second.
1 gram of hydrogen requires to liberate it from water, 34,500 gram-calories.
0·00001035 gram of hydrogen requires 34,500 × 0·00001035 = 0·357 gram-calorie.

Voltage required $\frac{0·357}{0·24} = 1·49$ volts.

In other words, if 1 ampère, at a potential of 1 volt, represents an energy of 0·24 calorie per second, while the amount of chemical work performed for 1 ampère in liberating hydrogen in the same time is 0·357 calorie, then it follows that the 1 ampère must be at a potential of 1·49 volts, in order that the energy of the current should be equal to the chemical work which it is doing (0·24 × 1·49 = 0·357).

The relations of electrical, mechanical, thermal and chemical energy may be thus recapitulated:

1 coulomb (C) = the unit of electrical quantity.
1 volt (V) = " " " " potential.
1 V × 1 C = 10,000,000 absolute units of work (centimeter-gram—second system.)

$1 V \times 1 C = \frac{10,000,000}{98,060,000} = 0·1020$ kilogrammeter of work.
= 0·2385 gram-calorie.
1 C flowing *per second* = a current of 1 ampère (A).
1 A × 1 V = 1 watt = 0·2385 gram-calorie *per second.*
= 0·1020 kilogrammeter of work *per second.*
= $\frac{1}{7\frac{1}{3}}$ of a French horse-power.
= $\frac{1}{7\frac{1}{4}}$ of an English horse-power.

1 A (1 coulomb per second) liberates 0·00001035 gram of hydrogen per second.

Therefore, 1 gram of hydrogen carries with it

$$\frac{1·00000000}{·00001035} = 96,540 \text{ coulombs};$$

but 1 C × 1 V = 0·2385 calorie;

therefore, for every volt required to liberate a chemically-equivalent weight, in grams, of an element, the expenditure of energy is

$$96{,}540 \times 0{\cdot}2385 = 23{,}040 \text{ calories};$$

and if Q be the quantity of heat given out by the combination of an equivalent weight of an element, in grams, the voltage required to liberate it from that combination is

$$V = \frac{Q}{23{,}040.}$$

It thus becomes possible to calculate the voltage theoretically required to electrolyse any combination of which the heat of formation is known.

The converse of this law is that the electromotive force of a galvanic cell will be given by dividing the algebraic sum of the heat set free in the chemical reactions taking place in the cell (calculated per chemical equivalent of metal dissolved or deposited) by 23,040, which latter quantity we may conveniently designate as the chemical-thermal equivalent of 1 volt.

Taking up the different theories which have been advanced to account for the facts of electrolysis, and leaving out of consideration the score or more of rather wild guesses hazarded by various philosophers, we may say that the germ of our modern theories is contained in the writings of Grotthus, as far back as 1805. Starting with the observed fact that the constituents of an electrolyte appear only at the terminals, or electrodes, and that no trace of them in an uncombined state can, by any means, be detected in the mass of the electrolyte between, Grotthus advanced the idea that each constituent retained its positive or negative character while in combination; that when the terminals are charged by connection with a battery the attraction of the poles is felt throughout the liquid, so that the molecules, heretofore having their constituents pointing at haphazard in any direction, are polarised by the electric attraction, and arrange themselves in a chain with their positive constituents all pointing towards the negative pole, and *vice versa*. This is the idea often re-

ferred to as the "Grotthus chain." When the attraction of the poles for the constituent in immediate proximity to them is stronger than the force binding the two constituents together, then the molecule at each pole is disrupted, the constituents are set free at the poles, while an interchange of partners takes place simultaneously along the whole chain, the positive constituent of each molecule uniting with the negative constituent of the next one back of it, and *vice versa*. In the accompanying diagram (*Fig. 1*), the

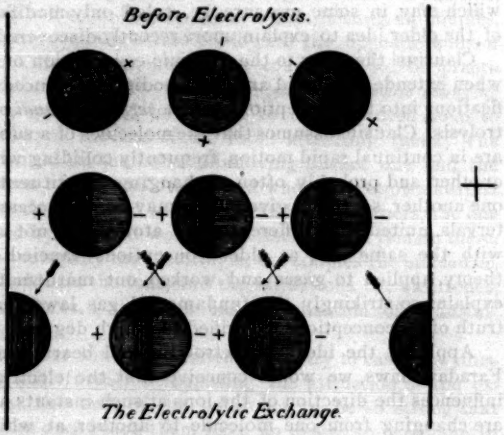


FIG. 1.

upper arrangement shows the molecules in fortuitous position before the application of the current; the middle row represents the molecules polarised in a chain by the influence of the charged terminals; the third row represents the arrangement after one exchange along the chain. Of course, the real number of molecules in the chain is probably millions to the inch; the diagram is intended merely to illustrate the mechanism of the change.

This theory of Grotthus, promulgated in 1805, explained wonderfully well the facts of electrolysis as far as they were

then known, and became untenable only when, in consequence of the acceptance of the dynamic theory of Clausius, in 1846, it became necessary to admit that the molecules could not thus be held at rest in a chain, but must be continually in a state of rapid motion. Grotthus' theory would also require that the concentration of the molecules in the solution should remain equal at all points between the electrodes, which is contrary to the facts discovered by Hittorf. The conception, however, on which this century-old theory is based, is still useful in leading up to the later conceptions, which may, in some measure, be styled only modifications of the older idea to explain more-recently-discovered facts.

Clausius' theory as to the dynamic constitution of gases, when extended to liquid and solid bodies, introduced modifications into the conceptions of the *modus operandi* of electrolysis. Clausius assumes that the molecules of a substance are in continual rapid motion, frequently colliding with one another, and probably often exchanging constituents with one another, so that a given atom may be, at successive intervals, united with different other atoms, and not always with the same one, as older conceptions fancied. This theory, applied to gases and worked out mathematically, explains so strikingly the fundamental gas laws that the truth of its conceptions is verified to a high degree.

Applying the idea to electrolytes, and bearing in mind Faraday's laws, we would conceive that the electric force influences the direction of the ions at such instants as they are changing from one molecule to another, at which instants they may be regarded as being potentially free from combination, and, therefore, susceptible to the directing force of the current. Only bodies thus capable of momentary dissociation into their ionic constituents will be capable of electrolysis. The result of this momentary pull on the ions, while they are changing partners, is to give them a directing tendency toward the electrodes. At the electrodes, the electric pull is strong enough to split the strongest molecule and attract to itself one ion, while the other finds new partners to combine with on its path toward the other electrode. Each ion, therefore, brings to, or neutral-

ises at the electrode, a definite quantity of electricity, and the current is thus conveyed by a species of *convection* through the electrolyte.

To use a homely illustration, imagine a ball-room, filled with couples of ladies and gentlemen waltzing and frequently exchanging partners. Then let us suppose that at the one end of the room there was opened to view something which powerfully attracted the attention of the ladies—let us say an exhibition of laces—while at the other end something was shown equally attractive to the gentlemen—if you like, the base-ball score-board. Now, while dancing in couples, both being equally attracted toward the opposite ends of the room, the movements of the couples would be practically uninfluenced by the attractions, but, *while changing partners*, each would be certain to be influenced so as to move toward the end of the room attracting them. The result would be, the ladies all moving toward one end, the gentlemen toward the other; and when the couples nearest to the ends separated in order to find new partners, the one attracted by that end would find itself free to remain there. Call the company the electrolyte, the couples the molecules, the individuals the ions, and the attractions the electrodes, and you have, I think, an exact realisation of Clausius' theory.

With your kind permission, I will try to carry the illustration still further. Supposing the attraction of the exhibits at the ends of the ball-room to be so strong that those who once reach them have no desire to re-engage in the dancing, but are held permanently there—the result would be a gradual breaking up of the company, the floor being thinned out gradually until all were gathered at the ends of the room. This represents the case when the electric potential is greater than the force holding the ions together in the molecule, and then we have continuous electrical decomposition to a finish.

Let us now imagine the attractive forces weaker. They would still exercise a directing influence on the ladies and gentlemen; but if the attraction was not so strong as the desire of the persons to dance, we can readily imagine that

those who were disengaged at the exhibits, after satisfying their curiosity, would turn their attention again toward the dancing, and it is certain that an accumulation of ladies, let us say, wishing partners, would constitute an attractive force on the gentlemen, which would soon become strong enough to neutralise the attraction at the other end of the room, and *vice versa*. Under these conditions the dancing might still go on, and yet a continually-changing company of temporarily-disengaged persons would always be seen viewing the attractions, which a person looking at, for the first time, might consider as representing so many permanently-disengaged couples. This condition represents the case when the electric potential is less than is theoretically necessary to separate the ions from each other and decompose the compound. With a low potential we have an accumulation of ions *to a minute extent*, on the electrodes, but the accumulation reaches a certain amount, and then stops. The higher the potential, the greater the accumulation, but it can never pass a certain limit. The strength of the desire of the persons gathered at the ends to re-engage in the dancing is measured by their real love of dancing minus the strength of the attraction which drew them there.

While the attracting force, therefore, remains less than the love of dancing, there will always be couples engaged in dancing, and the gatherings at the ends of the room cannot absorb all the dancers. While the acting electric potential remains less than the force with which the atoms tend toward each other in the molecule, there cannot be complete decomposition of the electrolyte, there can only be a gathering of ions on the electrodes, which cannot surpass a given ratio *to the number of momentarily free ions in the electrolyte*. When the acting potential just equals the theoretical voltage necessary for complete decomposition, this ratio becomes unity; that is, as many ions are set free at the electrodes in a given time as are set momentarily free, or as are potentially dissociated in the body of the electrolyte during the same time; and from then on, the ions accumulate without limit in quantitative proportion to the quantity of electric current passing, until the electrolyte is completely decom-

posed. This, however, would be an extremely slow operation. But, suppose the acting potential measurably larger, the ions are then forced apart through the body of the electrolyte, and form a steady procession toward each electrode. In other words, when the attraction of the electrodes is greater than that of the ions for each other, they incontinently take leave of each other and set up a procession toward each electrode, as we might imagine the ladies and gentlemen separating throughout the length of the ballroom and setting up processions toward each end, passing each other, with some friction it may be, and possibly the gentlemen making more rapid progress toward their end than the ladies toward theirs.

The last sentence gives the key to the valuable discover-

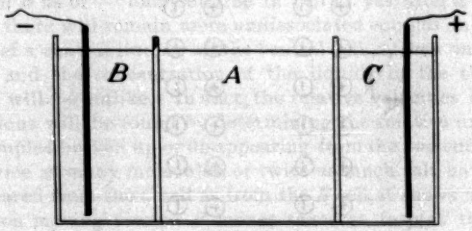


FIG. 2.

ies of Hittorf. It was well known before his time that, when electrolysing a solution, it gradually becomes impoverished around one electrode and concentrated around the other, if means are taken to prevent diffusion during the experiment. Hittorf, for instance, electrolysed a copper sulphate solution with an insoluble anode, using two porous partitions to separate the electrolyte into three compartments, one containing each electrode and one midway between (see *Fig. 2*). After passing the current for some time, it was found that the solution in *B* was much weaker than that in *C*, while the strength of the solution in *A* remained unchanged. On analysing the solutions and weighing the copper deposited, it was found that 64·4 per cent. of the copper had come from compartment *B*, and only 35·6 per cent. from compartment

FIG. 3.

C. Using the same apparatus, Hittorf tested the salts of many metals with analogous results.

The question at once arises: "What is the reason for this?" Hittorf's explanation is as follows:

The changes of concentration are satisfactorily explained by supposing the ions to migrate through the electrolyte toward the electrodes at a different rate of speed. If they moved with equal velocity, each outside cell would lose an equal number of couples in a given time; if, however, one moved faster than the other, the outside cells would lose a different number of couples, which would change the concentration in the cells. If, for instance, in *Fig. 3*, the ions passing toward *B* move twice as fast as those moving toward *C*, then, while just the same number of + ions will be set free in cell *B* as of — ions set free in cell *C;* yet after a given time there will remain more undissociated couples on the *B* side of a central line, or of the central cell *A*, than on the *C* side, and the concentration of the liquids in the outside cells will be unlike. In fact, the relative velocities of the two ions will be found by determining the relative number of couples broken up or disappearing from the two end cells. If twice as many molecules, or twice as much salt, have disappeared from the *C* cell as from the *B* cell, it shows us that the ion moving toward *B* moves twice as fast as the ion moving toward *C*, as can easily be seen by a study of *Fig. 3*.

Hittorf thus determined migration values for the velocities of the ions in many electrolytes, and found that the quantity of the current passing had no influence on the relative velocities of the ions, but that the concentration of the solution under examination had considerable influence. Starting with a concentrated solution, the relative velocities of the two ions changed as the solution was diluted, *until a certain dilution was reached, after which there was no further change in the relative velocities*. This behavior was found to be characteristic of all electrolytes.

The application of Hittorf's discoveries to the study of aqueous solutions decided many vexed chemical problems. For instance, does tin tetrachloride exist in solution, or is it a mixture of stannous chloride and hydrochloric acid? On

applying his methods to the study of stannic chloride solution, Hittorf found that the tin had no migration value at all—it stood still; and further, the chlorine traveled toward the anode with exactly the same velocity as did chlorine in a dilute solution of hydrochloric acid. The conclusion was certain, therefore, that there was hydrochloric acid in the solution, the hydrogen of which, evolved at the cathode, reduced tin from the *stannous chloride* present. In a similar manner, it was proven that the ions of some complex salts were quite different from what they had formerly been supposed, for instance:

Salt.	*+ Ion.*	*— Ion.*
K_4FeCy_6	K_4	$FeCy_6$
$KAgCy_2$	K	$AgCy_2$
Na_2PtCl_6	Na_2	$PtCl_6$
K_2HgCl_4	K_2	$HgCl_4$

Kohlrausch made the next great advance in our knowledge of the mechanism of electrolysis. He devised extremely accurate apparatus for measuring the conductivity of electrolytes. If we take the conception of Faraday and Clausius that electrolytic conduction is a species of electric convection from one electrode to the other, then the conductivity should depend simply on the number or concentration of the electricity-carrying ions between the electrodes. If the solution be diluted one-half, there will be only one-half as many ions between two fixed electrodes of given size, and therefore the electric conductivity should be exactly one-half; or the conductivity should be exactly proportional to the number of ions between the electrodes. Expressing it in another way, the conductivity should be inversely as the dilution of the solution.

Kohlrausch introduced a new expression. He calls λ the molecular conductivity, that is to say, the electric conductivity divided by the relative number of molecules between the electrodes. For instance, the molecular weight of potassium chloride is 74·5. A solution containing 74·5 grams of this salt to 1 liter is called a normal solution, whose concentration is 1, because it contains a molecular weight, in grams, in one unit of volume. Dilute this to 2 liters by

adding pure water, and the solution would then be said to have a concentration of one-half, or a dilution of two. If the specific conductivity of the normal solution (compared to mercury = 100,000,000) is 918, then the specific molecular conductivity would be

$$\frac{918}{1} = 918.$$

The conductivity of the dilute solution being 474, the molecular conductivity for this dilution is $474 \div \frac{1}{2} = 948$, one-half being the concentration.

Kohlrausch examined solutions up to dilutions of 100,000, and determined, with great precision, that the molecular conductivity *increased* with increasing dilution, until it reached a certain limiting value, characteristic of each salt, after which it remained constant. The limiting values of the molecular conductivity were thus determined for solutions of numerous salts, and a discussion of these values soon revealed very interesting relations. It was easily observed that there was an approximately constant difference between the molecular conductivity of similar salts of similar bases. For instance, Ostwald found

HCl — NaCl	= 281·8	KCl — NaCl	= 22·8
HBr — NaBr	= 282·1	KBr — NaBr	= 22·5
HI — NaI	= 280·6	KI — NaI	= 23·0

If these differences are constants, it follows that the molecular conductivity of a salt is composed of two factors, one of which depends on one constituent and one on the other, and that the molecular conductivity is merely the sum of the conductivities of the ions.

It was not a difficult step to connect this conductive capacity of the ions with the differing velocities of the ions, or their "migration values," determined by Hittorf. (Kindly bear in mind we are considering here merely conductivity, and not decomposition.) The conductivity of the salt is the sum of the conductivities of its ions, but these are proportional to the velocities of the ions; therefore, the conductivity of the salt is proportional to the sum of the velocities of the ions, that is

$$\lambda = u + v$$

Now, if in a given time the anion moves a distance n, while the cation in the same time moves $1 - n$, the relative velocities u and v are as n to $1 - n$; therefore,

$$v = n\,\lambda$$

and

$$u = (1 - n)\,\lambda$$

n being Hittorf's migration number for the anion.

Using Hittorf's migration numbers for the ions, and combining them with his own determinations of the limiting molecular conductivities, Kohlrausch calculated the following ionic conductivities:

K	= 52	Cl	= 54
Na	= 32	I	= 55
Li	= 24	NO_3	= 48
Ag	= 42	ClO_3	= 42
H	= 272	$C_2H_3O_2$	= 26
½ Ba	= 30	OH	= 143
½ Mg	= 26		
½ Zn	= 24		

The sum of the ionic conductivities of K and ClO_3, for instance, gives the molecular conductivity of $KClO_3$.

It is worthy of remark, at this point, that the heats of formation of chemically-equivalent weights of salts are also strictly additive quantities, being the sum of factors characteristic of each ingredient, if the heats are taken for the formation of the salt dissolved in excess of water, *i. e.*, *in dilute solution.* This analogy between the molecular heat of formation in dilute solution and the specific molecular conductivity in dilute solution is certainly interesting, and possibly points the way toward many discoveries in the direction of deducing molecular properties from the constants of the atoms.

We will next take up the developments in electrolysis, due to the acuteness of Arrhenius (1882). He viewed the question of the increase of molecular conductivity with increasing dilution up to a certain limit, in a different light from his predecessors. He imagined this peculiar conduct to be due to the fact that, in general, not all the molecules between the electrodes take part in carrying the current,

but only a part of them are "*active*" and another fraction "*inactive*." This distinction of active and inactive molecules is of the greatest importance in the evolution of Arrhenius' ideas. The increase in molecular conductivity with dilution would, therefore, be due to an increase in the proportion of active molecules, until when all became *active* the molecular conductivity reached its maximum, and, after that, further dilution would have no effect.

Now, the idea of *active and inactive mass* was a conception already introduced into chemistry by Guldberg and Waage, and Arrhenius put to the test at once the query whether the proportion of *active molecules* as determined by the molecular conductivity had any relation to the *active mass*, which measures the facility of a material to take part in chemical reactions. The result of the experiments, confirmed later by numerous experimenters, and in particular by Ostwald, was a complete identification of the two functions. For instance, Arrhenius measured the molecular conductivities of seven acids at similar dilutions, and the relative numbers obtained compared as follows with the relative avidities of these same acids, as determined in purely chemical ways by Thomsen:

RELATIVE AVIDITIES.

	From Chemical Tests.		*Calculated from Conductivity.*
Nitric acid	100	(standard)	100
Hydrochloric acid	98		92
Hydrobromic acid	89		86
Hydriodic acid	79		92
Sulphuric acid	49		47
Phosphoric acid	13		22
Acetic acid	3		8

These measurements of Thomsen were not as satisfactorily made as could be wished, and Ostwald devised other much more reliable and accurate chemical tests of the avidities of the acids, viz.: the speed with which the acid inverted cane-sugar, and the catalysis of methyl-acetate. Taking the activity of hydrochloric acid as 100, Ostwald examined thirty-four acids, whose relative avidities varied from 100 to 0·4, and compared this series with the molecular

conductivities expressed on the same scale (HCl = 100). The result was a most striking proof of Arrhenius' ideas, the deviations between the chemical and electrical series being in every case within the experimental errors. It was, therefore, proved, at least for these thirty-four acids, that the facility of reaction, or relative avidity, varies directly as the molecular conductivity for electricity, *i. e.*, as the proportion of active molecules.

The question at once arose: "In what respect do the *active* differ from the *inactive* molecules?" Arrhenius supposed at first that the *inactive* were polymerised molecules, which on dilution became depolymerised, and, therefore, *active*. The further developments, however, soon caused him to drop this idea and to advance one of the most startling theories of modern chemistry.

The next step was made by studying carefully the law according to which the molecular conductivity increases to a maximum, for this must also be the law governing the change in chemical avidity. Kohlrausch had observed that with acids conducting well (strong acids) the relative increase in molecular conductivity, on dilution, was not so great as the relative increase in the molecular conductivity of weaker acids. In very weak acids the molecular conductivity increased nearly as the square root of the dilution. He also observed that if one acid conducted better or worse than another at any dilution, it did so at all dilutions; they never changed their relative positions on dilution. It thus appeared that the molecular conductivities of the acids must all be approaching the same limiting value, and that at infinite dilution the molecular conductivities, and therefore the relative avidities of the different acids, become all alike; in this case all the molecules have become *active*. At lower dilutions the activity of the acids are in direct proportion to the relative number of active molecules, *i. e.*, to their molecular conductivity.

Ostwald showed further, by his experiments on the thirty-four acids, that the limiting value of the conductivity of bibasic, tribasic and tetrabasic acids is sensibly only one-half, one-third and one-fourth that of an *equivalent* solution

of a unibasic acid. To have the same degree of activity at great dilution, it is therefore necessary to compare, ***not equivalent, but molecular*** quantities of these acids. That is, at great dilution,

$$HCl = HI = HBr = H_2SO_4 = H_3PO_4 = H_4C_2O_2.$$

It therefore results that the active ions of these latter acids cannot be

$$H_2 - SO_4,\ H_3 - PO_4,\ H_4 - C_2O_2,$$

but must be

$$H - HSO,\ H - H_2PO_4,\ H - H_3C_2O_2.$$

This rule is true of all polybasic acids, and deviations from the rule at lower dilutions are caused by differences in the degree of partition into *active* and *inactive* molecules.

Arrhenius' ideas were further developed under the influence of Van't Hoff's discoveries of the osmotic pressure of solutions.

Van't Hoff prepared diaphragms impervious to salts in solution, but permeable to water. On placing such a diaphragm over the mouth of an inverted funnel, as in *Fig. 4*, nearly filling this with pure water and placing it in a solution of cane-sugar, the water is seen to rise in the stem of the funnel to balance the pressure exerted by the sugar molecules against the diaphragm. By very careful experiments, with more complicated apparatus, it was found that the pressure thus exerted (osmotic pressure) was exactly the same pressure as would be exerted by the same quantity of sugar if it occupied the volume of the solution and *existed in the gaseous state* at the temperature of the experiment. In other words, if we imagine the water of the solution all removed, the sugar to be gasified in the same space, its resulting gaseous pressure is the same as the osmotic pressure, or the pressure with which it tends to diffuse through the impermeable membrane. Even further than this, it has been shown that the osmotic pressure increases $\frac{1}{273}$ for each degree of rise in temperature—exactly the gas coefficient. The equation for osmotic pressure is therefore the well-known gas formula

$$p\,v = R\,T.$$

To illustrate briefly: A molecule of sugar weighs 340 ($H = 1$). If dissolved in water to 1 liter of solution, its volume becomes 1 liter. But if gasified at 0°, its vapor would theoretically occupy 22·3 liters; therefore, if compressed into one liter, its pressure would be 22·3 atmospheres. If a solution contained only 10 grams of sugar to the liter, the osmotic pressure should be $\frac{1}{34}$ of 22·3 atmospheres, or 0·656 atmosphere at 0°. Pfeffer measured the osmotic pressure

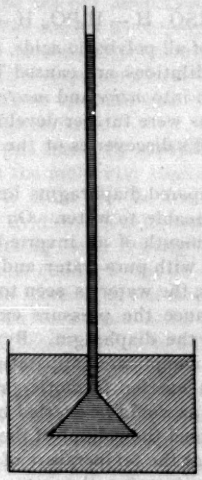


FIG. 4.

of this solution at 0° as 0·649 atmosphere. Many other solutions have been investigated with equally striking results.

However, some solutions investigated by Van't Hoff showed a deviation from the above rule. They gave greater osmotic pressures than the formula required—up to double the pressure—so that for these cases the formula had to be written

$$p\,v = i\,R\,T$$

where i was a factor varying up toward a value of 2. It was also observed that in such solution the deviation from the gas law increased with the dilution, so that i approached 2 as the liquid approached infinite dilution.

Arrhenius was the first to notice that all the solutions showing this anomalous behavior were *electrolytes*, and to advance the idea that in such solutions the salts were already partly separated into their ions, which increase in the number of molecules would explain the increase in the osmotic pressure, and cause the irregularities in the boiling and freezing points of such solutions observed by various experimenters.

We have thus reached a statement of the modern theory of electrolytic dissociation into ions in solutions. In 1887, Arrhenius made a memorable communication on this subject to the Stockholm Academy, in which he connects his new ideas with his older discoveries in the following words:

> "The difference between *active* and *inactive* molecules consists in that the first are split into their *ions;* the latter not.
>
> "Only the free ions take part in the conducting of electricity and in chemical reactions; thence results the proportionality between the properties of electric conductivity and chemical activity.
>
> "The ions behave in the solution as independent molecules; thence result the deviations which electrolytes show from Van't Hoff's gas law for osmotic pressure."

The next step in the evolution of this theory, the proof of these propositions, was to be found in determining experimentally the parallelism of these deviations; in other words, to show that the variations in the coefficient i of Van't Hoff's formula are identical with the variations in molecular conductivity and chemical activity noted by Arrhenius.

If we let

i = the relation between the real number of molecules present and that called for by the formula of the undissociated compound (Van't Hoff's coefficient);

a = the fractional number of molecules dissociated (Arrhenius' proportion of *active* molecules);

n = the number of ions into which each molecule dissociates;

then

$1 - a$ = the fractional number of undissociated molecules, and, by definition,

$$i = \frac{n\,a + (1 - a)}{1} = 1 + (n - 1)\,a.$$

But if, as Arrhenius postulates, the molecular conductivity varies directly as a, and, at infinite dilution, a becomes equal to 1, then it follows that the value of a at any given dilution is simply the ratio of the molecular conductivity at that dilution (μ_v) to the molecular conductivity at infinite dilution (μ_∞), or

$$a = \frac{\mu_v}{\mu_\infty}$$

and, therefore,

$$i = 1 + (n - 1)\,\frac{\mu_v}{\mu_\infty}$$

This reasoning predicted and rendered necessary the above simple relation between the deviation of the osmotic pressure of a solution from the simple gas law, and its variations in electric conductivity; between which quantities no relation had ever before been suspected.

To test this formula, Arrhenius investigated ninety solutions, twelve of which were non-conductors, fifteen contained bases, twenty-three acids, forty salts. The truth of the relations affirmed, or, rather, predicted, was proven decisively, and, later, more exact determinations have confirmed it even more strikingly.

If this theory of electrolytic dissociation really be a law of nature, then the following conclusions must be true:

(I) Since the ions are independent of each other, it does not matter with what element they were formerly united before dissociation; and the properties of the salt solution, at the limiting dilution where a equals 1, must become the binary sum of the properties of the two ions; all its properties must be strictly additive.

We have already seen how Kohlrausch has proven that the molecular conductivity at the limiting value is an additive quantity, and I also wish to call attention again to my previous observation that the heat of formation of the salts, in dilute solution, is also a strictly additive quantity.

(II) Only the *ions* show chemical activity. Therefore, as soon as an element exists in solution, *not as a simple ion*, but as part of a complex ion, it shows no longer the characteristic reaction of that element. For instance, the ions of KCl are K and Cl, and silver nitrate precipitates the chlorine; but in $KClO_4$, the ions are K and ClO_4; Cl is no longer an ion, and silver nitrate no longer shows its presence in the solution.

Time does not permit me to dwell longer on the development of this theory, on the struggles of Arrhenius, Van't Hoff, Ostwald, Planck, Nernst and others, to convince the doubting world of science of its truth.

Ostwald and Planck proved that the law regulating the increase in molecular conductivity on dilution is the identical law governing the *dissociation of a gas into two constituents*, which is derived from mechanical considerations and confirmed by experiment. Budde and Kohlrausch calculated the absolute velocities of the ions through the electrolyte, from which could be deduced the mechanical force necessary to give the ions this velocity. For instance, it requires a force of 330,000,000 kilos to force the atoms of hydrogen through an electrolyte at the rate of 0·003 centimeters per second. This is not the force which holds the ions together, but only the force required to overcome the friction of the ions in passing through the solution. Its enormously high value is due to the wonderfully minute size of the atoms. Nernst called attention to the relation between this force and the diffusion constant. The force necessary to cause diffusion of salt from a concentrated to a weak solution is found to be of the same order, and practically identical with the force necessary to give the ions their velocity. We can, therefore, conclude that the velocity of diffusion and the velocity of migration of the ions are conditioned by the same kind of internal friction. Nernst has elaborated this

remarkable coincidence into a theory of diffusion which has thrown a flood of light on the working of the galvanic cell.

In concluding this condensed account of the most remarkable theory of modern chemical science, I wish to explain, from my own point of view, a conception of the theory which has rendered it much more acceptable to my mind, and quieted some persistent doubts as to the possibility of its truth.

Here I have some potassium, here some chlorine. I bring them together and they unite with tremendous energy. I accept it as an axiom that they cannot be separated again without the expenditure of an equal amount of energy. Yet, along comes an adherent of the dissociation theory, and says: "Dissolve the salt in a large amount of water, and it exists there completely dissociated, not merely into potassium and chlorine molecules, but into potassium and chlorine *atoms*." I confess I am dumbfounded by the assertion. To say that they had been returned to the molecular state, would have been hard to believe; but into the *atoms!* Where does the energy come from to bring the potassium and chlorine back to their elementary state, to say nothing of that required to resolve the potassium and chlorine molecules into atoms? I see no source of such energy. Your statement is incredible, viewed simply from the standpoint of the conservation of energy. To remedy this grave defect in the theory, Ostwald advanced the idea that perhaps the combination of the atoms of an element to form molecules was not such an exothermic operation as we were wont to suppose, but that it must really be a strongly endothermic operation, and that, therefore, the heat *set free* by the *separation* of the potassium and chlorine as *atoms* was the source of the energy necessary to break up the potassium chloride.

I confess that this explanation left matters worse than before. We must assume that potassium atoms unite to form potassium molecules with the *absorption* of a great amount of energy, contrary to every indication which chemistry gives in the opposite direction. If such an assertion can be proven (and there is not a single proof alleged or

even possible), we should have to accept it; but it stands at present as a mere gratuitous assumption, contrary to every fact we know, and, therefore, not in any way an acceptable solution of the difficulty.

Quite recently I have come to look at the problem in quite a different way, and have reached the following (to me) satisfactory conceptions. Imagine, if you please, two electro-magnets, as in *Fig. 5*, hanging by their conducting

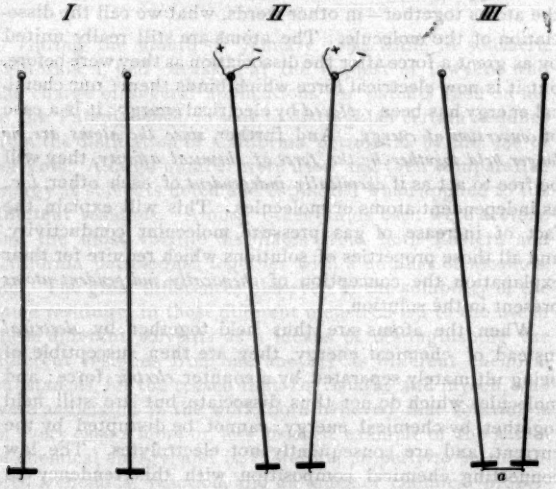


FIG. 5.

wires 1 foot apart, with their unlike poles, when magnetised, pointing toward each other, as in (I). Pass an electric current through them, and the magnetic pull will bring them, let us say, to within 3 inches, as in (II). Interrupt the current, and the apparatus is ready to illustrate my conception. Bring the magnets to within 3 inches of each other, and hold them there by placing an elastic band around them, as in (III). This physical bond represents the force of chemi-

cal affinity holding two atoms together in a molecule. Now, at a given instant, *throw off* the rubber band and *throw on* the electric current. If these operations could be performed instantaneously and exactly synchronously, the magnets would remain stationary. The physical bond has disappeared, yet the magnets remain in exactly the same spot as before, held together by the invisible magnetic pull. The disappearance of the physical bond represents, to my mind, the disappearance of the force of chemical affinity holding the atoms together—in other words, what we call the dissociation of the molecule. The atoms are still really united by as great a force after the dissociation as they were before, but it is now electrical force which binds them; our chemical energy has been *replaced* by electrical energy; it is a case of *conversion of energy*. And further, *since the atoms are no longer held together by the force of chemical affinity*, they will be free to act as if *chemically independent* of each other, *i. e.*, as independent atoms or molecules. This will explain the fact of increase of gas pressure, molecular conductivity, and all those properties of solutions which require for their explanation the conception of *chemically independent atoms* present in the solution.

When the atoms are thus held together by *electrical* instead of chemical energy, they are then susceptible of being ultimately separated by a counter *electric* force; and molecules which do not thus dissociate, but are still held together by chemical energy, cannot be disrupted by the current, and are consequently not electrolytes. The law connecting chemical composition with this tendency to "*dissociate*" has not yet been discovered, but when it is brought to light, we shall have a deeper insight into the ultimate nature of chemical combination than has ever before been vouchsafed to the inquiring mind of man.

Stated Meeting, January 21, 1896.

DR. H. F. KELLER, President, in the Chair.

ON THE USE OF ACETONE IN THE TECHNICAL ANALYSIS OF ASPHALTUM.

BY S. F. PECKHAM.

During the month of January, 1894, while in southern California, I had occasion, at the request of lawyers who had charge of several applications for patents then on file in the Patent Office, to seek to distinguish certain residues from the distillation of California petroleum by the use of solvents. A large number were used, and their comparative energy as solvents noted and estimated when applied to the different residues. Among other fluids used were acetone and the most volatile distillates from both Eastern and California petroleums, together with a number of alcohols, etc. The great differences observed in the solubility of the same residuum in these different menstrua led to the use of these different solvents as a means of distinguishing the different residues from one another as different chemical substances, for the reason that Dr. Salathé and myself, who were associated in the work, both believed that solution is in every case a more or less marked example of the action of chemical energy, and is, therefore, properly to be considered a chemical reaction, and an index of chemical properties.

It is, therefore, with no little surprise that I note, in the November number of this *Journal*,[1] a paper by Dr. S. P. Sadtler, in which he advocates the use of acetone as a substitute for petroleum ether in the technical analysis of asphaltum. It is true that my experience had been gained from an examination of artificial residues from natural

[1] *Jour. Frank. Inst.*, **140**, 383.

petroleums, in some instances still further removed from the natural bitumens by further treatment, and it was properly to be inferred that additional testimony should be obtained relative to the comparative solvent action of acetone and petroleum ether upon natural bitumens, before any final conclusions were to be reached relative to the use of acetone as such a substitute. In addition to this consideration is the equally important inquiry concerning the purpose of a technical analysis of asphaltum, and the proper interpretation of the results as heretofore obtained.

It is true, a great degree of indefiniteness has hovered around the use of the word "petrolene," and, especially, as regards the ultimate composition of the thing itself; but, after the results that have lately been obtained have been properly considered, it cannot be said that the portion of asphaltum soluble in petroleum ether, when ascertained by a careful and skilful manipulator, has any vague significance as a factor in the determination of the relation solid bitumens bear to each other. Not only when applied to different specimens of the same asphaltum, but also when applied to different asphaltums, do the varying proportions of the "petroleum ether soluble" become an indication of varying chemical properties and relations that further investigation respecting ultimate composition will doubtless render more definite, but from which technology need scarcely expect to receive any striking benefit. Moreover, in view of the fact that a large number of determinations are now on record, in which the solvent power of petroleum ether is a fundamental factor, it is quite necessary that, in the selection of any new solvent, an approximate equivalent for petroleum ether should be found; otherwise, both loss and confusion will follow inevitably.

The only object to be sought by a technical analysis of asphaltum is to thereby establish relations along certain lines that are but just beginning to be understood and appreciated. Results lately obtained have given a definiteness and approximate value to such analyses that removes them from the category of mere empirical factors, and places them more nearly in line with those "constants of

nature," which are to appear possessed of permanent value.[2]

I was, therefore, led in the light of my former experiences, and also in view of the striking dissimilarity of the results given by Professor Sadtler to any others on record with which I am familiar, to carefully test the use of acetone with petroleum ether in parallel experiments.

Considerably large portions of two samples of pitch, which I had brought from Trinidad, had been dried in my laboratory to a constant weight. One of these specimens (No. 1) was a sample of crude pitch, the other (No. 2) was a sample of Épurée, made on the island. Duplicate and very closely concordant analyses of these samples had been made by the process described by Miss L. A. Linton, in the paper read at the Cleveland meeting of the American Chemical Society.[3] Other portions from the same dried masses of pitch had been weighed for triplicate and quadruplicate analyses, but were not used, as the duplicate analyses were sufficiently concordant. Those weighed portions were used in duplicate to test the comparative solvent power of the acetone, with the following results:

No. 1.

Petroleum ether soluble	33·736	
Boiling spirits turpentine soluble	10·511	52·367 total bitumen.
Chloroform soluble	8·120	
Organic matter not bitumen . . .	10·851	
Inorganic matter	36·729	47·580 non-bituminous material.
	99·937 per cent.	

No. 1.

Acetone soluble	28·180	
Chloroform soluble	27·005	55·185 total bitumen.
Organic matter not bitumen . . .	9·835	
Inorganic matter	34·980	44·815 non-bituminous material.
	100·000 per cent.	

[2] *Am. Jour. Science*, to appear.

[3] *Jour. Am. Chem. Soc.*, to appear.

No. 2.

Petroleum ether soluble	33·625	51·875 total bitumen.
Boiling spirits turpentine soluble	15·575	
Chloroform soluble	2·675	
Organic matter not bitumen	10·150	48·125 non-bituminous material.
Inorganic matter	37·975	
	100·000 per cent.	

No. 2.

Acetone soluble	26·310	55·48 total bitumen.
Chloroform soluble	29·170	
Organic matter not bitumen	9·600	44·52 non-bituminous matter.
Inorganic matter	34·920	
	100·000 per cent.	

	No. 1.		No. 2.	
	Petroleum Ether.	*Acetone.*	*Petroleum Ether.*	*Acetone.*
Total bitumen	52·367	55·185	51·875	55·480
Non-bitumen	47·580	44·815	48·125	44·520

From these results it was at once manifest that acetone dissolved much less bitumen than petroleum ether, and, in addition, more than as much more of organic matter not bitumen, and mineral matter. They were also in line with the results given in illustration of his method by Professor Sadtler. In general, Professor Sadtler's results parallel my own, being very low in organic matter not bitumen, and in mineral matter.

To further test this matter, an acetone solution of pitch was prepared and evaporated to dryness at about 60° C. It yielded an organic residuum and deliquescent salt. The salt dissolved away from the bituminous and very viscous residue, and yielded, when evaporated to dryness, an organic residuum soluble in water. A portion of crude Trinidad pitch, exhausted with petroleum ether and chloroform, yielded to acetone a residue, a part of which was soluble in water, a part in sodium hydrate and a part in benzole. One gram of sample No. 1, after exhaustion in chloroform, yielded 1·59 per cent. of material to acetone.

To still further test the relation of the two solvents, equal portions of a very dry Egyptian asphaltum were exhausted under identical conditions with petroleum ether and acetone. The results are given below:

	Per Cent.
Petroleum ether soluble	38·03
Acetone soluble	8·68

Also, an Athabasca River maltha was exhausted in the same manner, with the following results:

	Per Cent.
Petroleum ether soluble	73·863
Acetone soluble	24·333

No difference was observed between the solvent power of cold and boiling acetone in either case. The dry Egyptian asphalt and the semi-fluid maltha exhibit the extremes to which any solvent of bitumen is likely to be applied, and the lack of parallelism is enormously large in both cases.

It appears to me that these results are conclusive, that acetone cannot be made an equivalent for petroleum ether in the technical analysis of asphaltum; first, because its solvent properties are unlike those of petroleum ether when applied to pure bitumen; and second, because it dissolves from a complex mineral, like Trinidad pitch, constituents that are not bitumen, thus defeating the very object of the work itself. According to my own observations, the action of acetone upon bitumens more closely approximates that of the alcohols than that of the true solvents of bitumen. If, therefore, acetone is to be used in the technical analysis of asphaltum, a new series of constants will, of necessity, have to be established, which in my judgment would lead only to confusion.

I am not prepared to judge of the merits of the apparatus suggested in Professor Sadtler's paper. The method by separatory funnels is simple, and capable of yielding results that are all that can be desired.

University of Michigan, January 3, 1896.

On the Oxidation of Diacetyl.

By Harry F. Keller and Philip Maas.

Diacetyl and benzile are the simplest representatives of the class of *a*-diketones in the fatty and aromatic series, respectively.

Their constitutions may be regarded as definitely established, since it has been shown that they each contain *two* carbonyl groups, and that these are *directly* united.

But in spite of the close analogy expressed in their formulæ, diacetyl and dibenzoyl show some very remarkable differences in their chemical deportment. In accordance with the general rule, the aromatic compound is distinguished by the greater stability of its molecule. It is true that when treated with alkaline hydroxides, benzile takes up 1 molecule of water, and is transformed by molecular rearrangement into benzilic acid,

$$C_6H_5 \cdot CO \cdot CO \cdot C_6H_5 + H_2O = \begin{matrix} C_6H_5 \\ C_6H_5 \end{matrix}\!\!>\!C(OH) \cdot CO \cdot OH$$

it does not, however, like diacetyl, appear capable of condensing into a quinogen or quinone.

$$\begin{matrix} CH_3 \cdot CO \cdot CO \cdot CH_3H \\ H\,CH_2 \cdot CO \cdot CO \cdot CH_3 \end{matrix} = \begin{matrix} CH_3 \cdot C - CO \cdot CH \\ \| \qquad\quad \| \\ CH \cdot CO - C \cdot CH_3 \end{matrix}$$

It is further well known that benzile resists the action of nearly all oxidising agents. Concentrated nitric acid and chlorine, for example, which are used in its preparation from benzoin, appear to be without action upon it. Chromic acid mixture converts it slowly into benzoic acid.

Diacetyl, on the other hand, is quite readily oxidised. The first observation in this direction was made by Fittig and one of us,[1] who found that, under certain conditions, this

[1] *Annalen*, **249**, 207.

body reduces silver solutions. To explain this, it was assumed that aldehyde and acetic acid are first formed by hydrolysis,

$$\begin{matrix} CO \cdot CH_3 \\ | \\ CO \cdot CH_3 \end{matrix} + H_2O = CH_3 \cdot CHO + CH_3 \cdot CO \cdot OH$$

and the aldehyde further oxidised to acetic acid.

$$CH_3 \cdot CHO + Ag_2O = CH_3 \cdot COOH + 2Ag.$$

From the following experiments it will be seen that the oxidation of diacetyl into acetic acid is readily effected.

Two grams of diacetyl were dissolved in rather more than 25 c.c. of a 3 per cent. solution of hydrogen dioxide, and the mixture heated in a flask provided with an inverted condenser. Color and odor of the diketone soon disappeared, while the liquid acquired a strongly acid reaction. An excess of barium carbonate was now added, and, after warming for some time, the solution filtered off. The filtrate was evaporated to a small volume and then allowed to stand in a desiccator over sulphuric acid. At first, long needle-like crystals radiating from a common center separated, and, after evaporation to dryness, a crystalline mass weighing 6·2 grams remained. This is nearly the theoretical quantity—6·34 grams—required for $Ba(C_2H_3O_2) + H_2O$.

The salt gave all the reactions peculiar to acetates. Warmed with concentrated sulphuric acid, it emitted pungent fumes, and with alcohol and sulphuric acid, the fragrant odor of acetic ether. Ferric chloride produced a blood-red color in the aqueous solution.

The greater part of the barium salt was dissolved in water and precipitated with silver nitrate. Recrystallised from hot water, the silver salt formed the characteristic shining and flexible needles, darkening when exposed to daylight. It was analysed with the following results.

I. ·6075 gram yielded ·3919 gram metallic silver.
II. ·7234 " " ·4671 " " "

	Calculated for:	*Found:*	
	$Ag.C_4H_3O_4$	*I.*	*II.*
Ag	64·59 per cent.	64·51 per cent.	64·57 per cent.

Hence, it follows that hydrogen dioxide quantitatively converts diacetyl into acetic acid.

Permanganic acid acts on diacetyl in an analogous manner. When a solution of potassium permanganate is added to diacetyl dissolved in water and acidified with sulphuric acid, the purple color is instantly discharged.

·5341 gram of the diketone was dissolved in water and sulphuric acid added: 92 c.c. of a permanganate solution of the standard 1 c.c. = ·0058 Fe., were decolorised by this liquid. This represents ·077 gram of oxygen, while theory would require ·098 gram.

In another experiment 3 grams of diacetyl were taken and 64 c.c. of a 2·5 per cent. solution of permanganate run in. This would correspond to ·405 gram of oxygen, instead of ·55 gram calculated.

That acetic acid is actually the main product of this oxidation, was proved by distilling the solution which resulted from the last experiment. By neutralising the distillate with barium carbonate, filtering and evaporating, about 4·5 grams of the acetate were obtained. It was tested in the manner already described.

Numerous experiments were made with nitric acid as the oxidising agent.

Having observed that, when highly concentrated, this acid acts upon diacetyl, even at ordinary temperatures, with formation of oxalic acid, we hoped to obtain intermediate products, perhaps ketonic acids, by working at low temperatures, and by diluting the nitric acid. These expectations have not been realised.

Five grams of diacetyl were mixed with nitric acid, specific gravity 1·48, in considerable excess. The temperature slowly rose to about 50°, when the action became exceedingly violent, torrents of red vapors being emitted. After the reaction ceased, the residue was dissolved in warm water; upon standing, a few tabular, rhombus-shaped crystals deposited. A larger crop of prismatic crystals formed after concentrating the solution, and these were easily recognised as oxalic acid. They melted at 100·5°, and their aqueous solution was precipitated by calcium chloride and silver nitrate. Weighed portions of the crystals required

the same quantities of standard solutions of caustic potash and permanganate as the same amounts of pure oxalic acid.

We are, at present, unable to say whether or not the tabular crystals first obtained were oxalic acid. Their total amount was less than a decigram. They blackened on heating, and repeated determinations of the melting point gave 128°. A weighed quantity was neutralised by one-fifth less of standard alkali than the same weight of oxalic acid. Otherwise, the reactions were like those of the latter acid.

In a second experiment, 2 grams of diacetyl were carefully poured on top of the nitric acid, so that the liquids could mix only by diffusion. The vessel was placed in cold water. After two weeks, the odor of diacetyl had disappeared, and the liquid was full of flat, prismatic crystals, which proved to be pure oxalic acid.

Ordinary nitric acid acts but slowly in the cold. At 50° to 60° the reaction becomes very violent, the sole product being oxalic acid. Similar observations were made when an acid diluted with its own volume of water was employed.[2]

[ABSTRACT.]

A FERRUGINISED TREE.

By Oscar C. S. Carter.

On the farm of Wm. Teas, situated about a mile from Three Tuns, Montgomery County, Pa., is a quarry of loose, disintegrating sandstone, of a light-yellow color. The first few feet of the surface is made up of loose sand, resulting from the decomposition of the underlying sandstone. Below the sand is the crumbling sandstone rock. This rock is made up of grains of sand bound together with a cement of feldspar. The feldspar is chalky-white in appearance, and is decomposing, which accounts for the crumbling

[2] Fileti and Ponzio (*Gazz. chim. ital.*, **25**, 233), in a paper on the oxidation of ketones, state that methyl-ethyl ketone, by warming with nitric acid, specific gravity 1·38, is converted into diacetyl. They also observed the destruction of this diketone by nitric acid, but do not appear to have examined the products.

nature of the sandstone. Soils derived from sandstone rocks of this nature are loose and porous, permitting moisture, air and heat, to act on the roots of growing crops, and yet the feldspar yields enough clay to hold a certain amount of moisture, and to prevent the soluble fertiliser from draining away too rapidly. Then, again, the feldspathic cement contains potash, which is a valuable plant food. This cement of feldspar is characteristic of certain tracts of sandstone in parts of the New Red belt of Montgomery County. A piece of this rock will generally show the chalky-white, decomposing feldspar, and the resulting soils are fertile. While digging sand some time ago, Mr. Teas came across what seemed to be a mass of iron ore, from 6 to 10 inches in diameter, and about 15 feet long. It was found about 10 feet below the surface, in the sand, and only a few inches above the solid rock. This mass of ore had the exact outlines of the lower part of a tree. On loosening the mass from the crumbling sandstone, it was broken. A close examination showed that it was a tree that had been ferruginised, or pseudomorphosed into iron ore. The bottom of the log was harder than the top, as it was found in the quarry. The rough outside bark could be clearly distinguished, and on one piece a knot was observed, which was entirely converted into iron ore.

One fact, which settles beyond all doubt that it was part of a tree, is that some parts of the trunk are not entirely converted into iron ore, but still show their woody texture. These parts are partially carbonised, and make a black streak on paper like charcoal. This part of the tree is an imperfect lignite.

The ore is the hydrated oxide of iron, known as brown hematite ($2Fe_2O_3 . 3H_2O$). In one or two places spots of yellow ochre are noticed, and, in one specimen, was noticed a little red ochre. Here and there, on some of the specimens, were noticed patches of the peculiar iridescent hematite. The great mass of the ore, however, was brown hematite. It is unusual to find masses of brown hematite in this sandstone of Mesozoic Age, although the coloring matter of our Montgomery County sandstones and red shales is due to red and brown hematite. The red shales often hold as

high as 7 per cent. of iron; one specimen from near Norristown, on the Stony Creek Railroad, which I analysed, contained 10 per cent. of ferric oxide. No workable beds of iron ore have ever been found in the sandstone of Montgomery County. The iron ore in this county is found in the clay and limestone and hydro-mica schist. * * *

The soil and rocks of this quarry and vicinity once contained enough iron to give them a distinct red color. As the rainwater gradually drained through the soil it finally removed the iron from the soil and rocks in the form of carbonate, and the color of the sandstone changed from red to light yellow. It is well known that if a fragment of wood or charcoal be placed in a chalybeate water the iron will be precipitated as hydrate. Therefore, when this water, charged with iron, came in contact with the tree, there took place an interchange of particles, the woody matter being replaced by the iron.

It is to be regretted that the entire tree was not safely removed from the sandstone and preserved, as finds of this kind are rare in the New Red sandstone. Good specimens, however, were obtained.

The influence of the reducing action of organic matter on the red coloring matter of soils and rocks is often noticed. On the country road between Eagleville and Arcola, there is a red and white sandstone containing irregular black patches of organic matter. On splitting the rock, layer after layer of this black carbonaceous matter is seen. The sandstone is only white where in contact with, or near to, the organic matter; the rest of the rock is red. The red coloring matter of the sandstone is due to red hematite. Water containing carbonic acid filtering through the bed planes, had dissolved the ferrous oxide, formed by the reducing action of the carbonaceous matter, and thus leached out the red coloring matter of the sandstone, leaving it white. Precisely the same kind of rock as the above was noticed in the New Red in a quarry near Three Tuns, not very far from where the iron tree was found.

Department of Geology and Mineralogy,
Central High School,
Philadelphia, January 21, 1896.

NOTES AND COMMENTS.*

REPORT OF THE NICARAGUA CANAL COMMISSION.

The New York *Herald* of recent date publishes what is declared to be a full abstract of the conclusions of the Commission of Engineers appointed by Congress to investigate the plans and estimates of the Nicaragua Canal Company.

If this account is to be credited, the report of the Commission casts grave doubt, not to say discredit, on the enterprise.

The *Herald's* account states that the Commission finds that the preliminary engineering has been so very imperfectly done as to leave the question of the feasibility of the plans proposed open to serious doubt, and that the data accessible do not justify the estimates of cost. The Commission doubles the estimates of the Company, making the figures $133,472,893, as compared with $69,893,660, the figures named by the promoters.

Among other things, the Commission recommends to Congress that $350,000 be appropriated to defray the expenses of additional preliminary engineering work, which is held to be necessary before the data will be accessible upon which to base a safe estimate of the cost of the canal. W.

THE INCANDESCENT ELECTRIC LAMP DECIDED TO BE EDISON'S INVENTION.

A recent decision of the Supreme Court of the United States (read by Justice Brown) sustained the Edison patent for the incandescent electric lamp, against the claim of the Consolidated Electric Light Company, representing the Sawyer-Mann patent.

The first point on which the decision was based related to an informality in the manner in which the Sawyer-Mann application was made; this being simply a legal technicality, it has no interest for us.

The second point related to the nature of the filament, and, in the opinion of the Court, Sawyer and Mann were not successful in finding a proper material for the purpose. Their claim "of a conductor composed of carbonised and fibrous material," the Court held, "is too broad to sustain the patent and must, therefore, be declared invalid. They could not, by such a claim, shut out all other investigators into the field of vegetable fibre. * * *" After examining some 6,000 different materials, Edison finally adopted bamboo as the best material, and it appeared that Sawyer and Mann had abandoned the materials they had used in their early experiments and adopted the material used by Edison.

The judgment of the Court below, declaring the Sawyer-Mann patent to be invalid, is for these reasons affirmed. W.

* Chiefly from the Secretary's monthly reports.

GROWTH OF THE ALUMINUM INDUSTRY.

The efficiency of the electro-metallurgical methods now exclusively employed in the production of aluminum, is strikingly shown by the figures of the following tabulation, representing the product of the United States since 1882. The first impetus to the industry was given in 1886, when the electric furnace plant of the Cowles brothers was fairly put in operation. In 1889, when the Pittsburgh Reduction Company entered the field with the Hall electrolytic process, another great advance in output was recorded; and the industry has since been steadily growing year after year.

Year.	*Pounds.*	*Year.*	*Pounds.*
1883	83	1889	47,468
1884	150	1890	61,981
1885	263	1891	150,050
1886	3,000	1892	259,885
1887	18,000	1893	339,629
1888	19,000	1894	550,000

The *Iron Age* estimates the American output of aluminum, in 1895, at 850,000 pounds, and believes that the production of the present year will reach the imposing total of 6,000 pounds per day, or over 2,000,000 pounds.

W.

PRODUCTION OF BESSEMER STEEL INGOTS AND RAILS IN THE UNITED STATES IN 1895.

Mr. James M. Swank has just published, in the *Bulletin* of the American Iron and Steel Association, the complete statistics for the year 1895, of the production of Bessemer steel ingots and Bessemer steel rails of all weights and sections, in the United States, except the comparatively small quantity of standard rails, and a larger quantity of street rails which were made by manufacturers from purchased blooms. In the statistics of ingots produced are included the production of the few Clapp-Griffiths and Robert-Bessemer plants, and also the production of steel castings by all Bessemer works.

"*Ingots.*—The total production of Bessemer steel ingots in 1895 was 4 909,128 gross tons, against 3,571,313 gross tons in 1894, showing an increase in 1895 of 1,337,815 tons, or over 37 per cent. The production in 1895 was much the largest in our Bessemer steel history. The following table gives our production of Bessemer steel ingots in the last ten years:

Years.	*Bessemer. Gross Tons. Ingots.*	*Years.*	*Bessemer. Gross Tons. Ingots.*
1886	1,269,190	1891	3,747,417
1887	2,936,033	1892	4,168,435
1888	2,511,161	1893	3,215,686
1889	2,930,204	1894	3,571,313
1890	3,688,871	1895	4,909,128

"With an estimated production in 1895 of over 1,000,000 tons of open-hearth steel, soon to be accurately ascertained, it is probable that our total production of steel in that year exceeded 6,000,000 tons. Great Britain's total steel production has never amounted to 4,000,000 tons in any year.

"The following table gives the production of Bessemer steel ingots by States in 1892, 1893, 1894 and 1895:

Ingots. *States.*	*1892.* *Gross Tons.*	*1893.* *Gross Tons.*	*1894.* *Gross Tons.*	*1895.* *Gross Tons.*
Pennsylvania	2,397,984	2,126,220	2,334,548	2,978,924
Illinois	879,952	314,829	581,540	866,531
Ohio	409,855	348,141	363,974	719,954
Other States	480,644	426,496	291,251	343,719
Total	4,168,435	3,215,686	3,571,313	4,909,128

"*Rails.*—The production of all kinds of Bessemer steel rails by the producers of Bessemer steel ingots in 1895 was 1,266,081 tons, against a similar production of 904,020 tons in 1894, 1,036,353 tons in 1893, and 1,458,732 tons in 1892. The following table shows the production by States of Bessemer steel rails by the producers of Bessemer steel ingots in 1892, 1893, 1894 and 1895:

Rails. *States.*	*1892.* *Gross Tons.*	*1893.* *Gross Tons.*	*1894.* *Gross Tons.*	*1895.* *Gross Tons.*
Pennsylvania	885,652	639,431	606,866	837,043
Illinois	450,542	232,260	225,869	324,950
Other States	122,538	164,662	71,285	104,088
Total	1,458,732	1,036,353	904,020	1,266,081

"When we shall have received the returns of the production of Bessemer steel rails from purchased blooms in 1895, it is probable that the total production of Bessemer steel rails in that year will be found to have exceeded 1,350,000 gross tons."

MEDICAL APPLICATIONS OF RÖNTGEN'S DISCOVERY.

From London *Nature*, we learn that the new photography has received the official recognition which is usually given to scientific discovery in Germany. Professor Röntgen has been honored by the Emperor, and the Prussian Minister of War has caused experiments to be made in order to discover whether the method can be applied successfully to army surgery. A series of photographs of bone injuries have shown so clearly the nature of the wounds and the position of imbedded projectiles that it has been determined to carry on the experiments on a larger scale.

"Medical science seems likely to benefit much by the application of Professor Röntgen's discovery. The *British Medical Journal* thinks, as an aid to diagnosis of obscure fractures and internal lesions generally, the new photography will be of great value. From our contemporary we note that already a beginning has been made in this direction, and Professor Mosetig, of Vienna, has taken photographs which showed, with the greatest clearness and precision, the injuries caused by a revolver-shot in the left hand of a man, and the position of the small projectile. In another case, the same observer detected the position and nature of a malformation in the left foot of a girl with entire success. Professor Lannelongue, of Paris, has also been successful in photographing some of his cases in his ward at the Trousseau

Hospital, and, assisted by MM. Oudin and Barthélemy, has submitted to the Academy of Sciences several negatives of human limbs. One of them represented a diseased thigh bone. The destroyed central portions had been penetrated by the light, forming white blotches on the plate. Another photograph was that of a tuberculous affection of the bone in a child's hand. The disease had been diagnosed, but photography brought complete confirmation to the diagnosis.

"The Berlin correspondent of the *Lancet*, referring to the practical use being made of the discovery, says in one case a finger which had sustained a compound fracture, and from which a sequestrum had been removed, was photographed by the new process, and the regeneration of the bone was thereby made visible. In another case, the position of a piece of glass embedded in the tissues was ascertained by the same method. Similar reports come from other universities, as, for instance, from Berne, where Professor Kocher has photographed a needle in a woman's hand; it had made its way under the skin some time ago, and had not been found by any other means."

In the United States, also, many accounts have appeared in the public prints relating similar successes in the application of the new photography to the diagnosis of obscure cases requiring surgical treatment, and it appears most probable that in this field the new method will yield results of much practical value. W.

ENGINEERING TOOLS AT POMPEII.

Under the title of "Things of Engineering Interest Found at Pompeii," Professor Goodman lately gave his inaugural lecture in the engineering department of the Yorkshire College, Leeds, the following abstract of which is gleaned from the *Scientific American:*

The lecturer remarked that he had recently visited Pompeii, and was not only charmed by the great beauty of the works of the ancient Romans, but also by their extreme ingenuity as mechanics—in fact, it was a marvel how some of the instruments and tools they were in the habit of using could possibly have been made without such machinery as we now possess.

After explaining the situation and destruction of Pompeii by showers of ashes and mud—not lava, as is usually supposed—in the year 79 A.D., Professor Goodman showed a series of about fifty lantern slides, prepared from photographs taken by himself in Pompeii last Easter. The streets, he explained, were used as waterways to carry off the surface water, and probably sewage, from the houses. The pavements were raised about a foot above the streets, and stepping stones were provided at intervals for foot passengers.

The horses and chariot wheels had to pass between, and in many places deep ruts have been worn by the chariot wheels in the stone-paved streets. The water supply of Pompeii was distributed by means of lead pipes laid under the streets. There were many public drinking fountains, and most of the large houses were provided with fountains, many of most beautiful

design. The amphitheater, although a fine structure, capable of seating 15,500 people, was small compared with many in Italy. The bronzes found at Pompeii reveal great skill and artistic talent. The bronze brazier and kitchener were provided with boilers at the side and taps for running off the hot water. Ewers and urns have been discovered with internal tubes and furnaces precisely similar to the arrangement now used in modern steam boilers. Several very strong metal safes, provided with substantial locks, have been found. The locks and keys were most ingenious, and some very complex. On looking at the iron tools found in Pompeii, one could almost imagine he was gazing into a modern tool shop, except for the fact that the ancient representatives have suffered severely from rust.

Sickles, billhooks, rakes, forks, axes, spades, blacksmiths' tongs, hammers, soldering irons, planes, shovels, etc., are remarkably like those used to-day; but certainly the most marvellous instruments found are the surgical instruments, beautifully executed, and of design exactly similar to some recently patented and re-invented. Incredible as it may appear, yet it is a fact that the Pompeiians had wire ropes of perfect construction.

A CURIOUS OCCURRENCE OF VANADIUM AND PLATINUM.

The *Engineering and Mining Journal* makes the statement, on the authority of "a reliable correspondent," that a firm of merchants in London, are in possession of some extensive deposits of coal, the ash of which contains considerable quantities of vanadium and the platinum metals. The coal yields 15 per cent. of ash, which gave, on analysis, 2·9 per cent. of vanadium, 0·23 per cent. of platinum metals (chiefly platinum). From these figures, it will be noticed that the metallic contents of 1 ton of the coal would be 141 ounces of vanadium and 11·24 ounces of platinum metals.

The value of this deposit, assuming that it is, as claimed, "very extensive and of fairly uniform contents," may be estimated from the fact that the present value of vanadium is from $40 to $45 per ounce (troy), and that of platinum, $13.50 to $14 per ounce.

If large quantities of vanadium could be supplied at low price, there would probably be a considerable demand for it, for the manufacture of vanadium black.

The exact location of this interesting deposit is, for obvious reasons, not disclosed, but it is believed to be in the province of Mendoza, in Argentina.

W.

ENGINEERING NOTES.

In connection with the *natural gas supply* in Western Pennsylvania, the following item from the *Iron Age* will be of interest, viz:

The Philadelphia Natural Gas Company, of Pittsburgh, has a larger supply of gas for their private customers than at any time within the past three years. In fact, the concern has more gas than its private consumers can use, and recently mailed to Pittsburgh manufacturers copies of a circular

in which the following prices are quoted: For the first 500,000 cubic feet, or part thereof, consumed per month, 15 cents per 1,000; for the second 500,000 cubic feet, or part thereof, consumed per month, 10 cents per 1,000; for all over 1,000,000 cubic feet consumed per month, 8 cents per 1,000, subject to the conditions of the regular form of contract.

The New York *Herald's* forecast of the report of the commission of engineers appointed to investigate the *Nicaragua Canal*, of which a brief statement appears in this impression of the *Journal*, proves to have been strictly correct. The outcome of this investigation, by a body of professional experts of the highest standing, is practically to double the estimate of cost made by the promoters, making it $133,472,893 instead of $69,893,660.

Proposals have been called for on the enlargement of the wheelpit of the *Niagara Falls Power Company*, to provide for three additional dynamos and turbines, to furnish 15,000 horse-power additional power for local use. The Acetylene Gas Company is reported to have closed a contract with the Power Company for 10,000 horse-power. Work on the Canadian power plant is also to be pushed.

M. Roger, the inventor and manufacturer of automobile carriages, has made application to the police authorities of Paris for permits to run a number of *horseless carriages* on the streets, for hire at the regular legal rate of 30 cents a drive, or 40 cents an hour when hired on the street. When hired from a cab-stand the charge is slightly greater. It would appear from this that the problem of operating such vehicles cheaply enough to compete with the regular "fiacres" has been solved.

The *Railroad Gazette* reports the construction, in 1895, of 31,893 *freight cars* in the United States, as compared with 17,029 built in 1894. This is an improvement, and indicates that the turn of the tide has come; but when the figures are compared with those of the years immediately preceding (51,000 in 1893, and 93,000 in 1892), it is seen that, to restore the industry to its normal condition, a substantial increase is still needed.

Electric street car companies in Tacoma, Wash., are to be required to repair all *damages to water pipes caused by electrolysis*. In repairing one of the principal avenues of the city, along which runs an electric car line, it was found that more than one-half of the surface and connecting pipes, running from the water main to buildings, had been so eaten away by the electric current grounded through the rails as to be useless. The pipes were replaced by the city at a cost of more than $1,000. All franchises hereafter granted will contain a clause that the company shall repair damage thus caused. W.

TECHNICAL NOTES.

A New Heavy Liquid for Mineral Determinations, proposed by Penfield, is prepared by mixing equal proportions of silver and thallium nitrate. This mixture fuses at 75° C., forming a clear mobile liquid, having a density of 4·5, and which mixes with water in all proportions. It can, therefore, be used to

separate minerals having densities below 4·5, from those which are lighter. London *Nature* gives the following further details:

"When still heavier particles have to be separated, the proportion of thallium may be increased. When the ratio is 3 : 4 the mixture fuses below 100° C., and has a density of about 4·7. At 2 : 4 the fusing point becomes 150° C., and the density 4·8; at 1 : 4 it is about 4·9, and fusion only takes place at 200°. Finally, when pure thallium nitrate is used, the point of fusion is 250° C., and the density closely approaches 5. This high range of densities, together with the fact that the salts do not attack many minerals, make the liquid especially valuable for mineralogical purposes. A convenient separator is described by the same author. It consists of a thimble-shaped cup, into which a wide tube is made to fit. The tube can be closed at the bottom by a hollow plug. This plug being removed, the heavy liquid is poured through the tube into the thimble, and the minerals are thrown in and stirred. The heavy particles sink into the thimble, and may be removed by closing the tube with the plug and withdrawing the thimble. The latter is then replaced, and the operation repeated with dilute liquid. With some practice an elaborate separation by densities is rapidly and easily accompliished."

Anthion is the commercial name under which a new and powerful oxidising agent is placed upon the market by the manufacturers, the *Chemische Fabrik*, of Berlin.

It is potassium persulphate, formed by the electrolysis of an aqueous solution of the sulphate. The persulphate is precipitated about the anode, and may be separated and purified by re-crystallisation from its solution in warm water.

It is said to be employed advantageously in dyeing and bleaching, but its greatest utility is found in photography, where it is applied successfully for the removal of the last traces of hypo from photographic prints. These residual traces of the hypo used in fixing the photographic image, which resist removal even after prolonged washing—and which are held to be responsible for the gradual deterioration of photographic prints—are said to be completely removed by the oxidising action of the persulphate.

Sodium as an Impurity in Commercial Aluminum has been found by Moissan to be present in the electrolytic aluminum produced at La Praz (France), Neuhausen (Switzerland) and Pittsburgh (U. S.), in quantities varying from 0·1 to 0·3 per cent. He finds that the presence of this small quantity of sodium renders the metal liable to be slowly attacked by water, and also decidedly alters the character of alloys of aluminum. He attributes to this cause certain discrepancies in the results of various investigators respecting some of the properties of aluminum.

An ink for *writing on glass*, as with ordinary ink, is made, according to the *Microscope*, of bleached shellac, 10 parts; Venice turpentine, 5 parts; lampblack, 5 parts. The ingredients are commingled and thinned down to the proper consistency with spirits of turpentine.

BOOK NOTICES.

National Car and Locomotive Builder; American Engineer and Railroad Journal.

The above-named technical journals have been consolidated, and, beginning with the impression for January, 1896, are now published monthly, under the title of *American Engineer, Car-Builder and Railroad Journal.* The editorial department will be under the supervision of Mr. M. N. Forney, assisted by Mr. Waldo H. Marshall. W.

Sixteenth Annual Report of the United States Geological Survey to the Secretary of the Interior, 1894-1895. Charles D. Wolcott, Director. Part III. Mineral Resources of the United States, 1894; Metallic Products. David T. Day, Chief of Division. Washington: Government Print, 1895.

The work above entitled forms an imposing royal 8vo of some 650 pages, and deals apparently in an exhaustive way with the metal industries of the United States. The several divisions of the subject have been entrusted to well-known experts, whose names are in most cases a sufficient warranty for the value of their respective contributions. Among those we need only name Birkinbine (iron ores), Swank (iron and steel), Kirchhoff (copper, lead, zinc), Weeks (manganese), Rölker (tin), Garrison (chromium, tungsten).

The delay in the appearance of this volume, which seems to be unavoidable in the issue of public documents, naturally detracts somewhat from its interest, but nothing whatever from its permanent value as a work of reference.

The departure taken in the change of form to that of the royal octavo makes the publication conform with the annual reports of the Survey, of which it forms a part, and is a decided improvement.

It may interest our readers to know that the cost of printing and binding is no longer charged for this book, and that by making prompt application to a Senator or Representative the volume may be obtained without cost.

W.

The Lehigh University School of Mechanical Engineering, under the direction of Prof. J. F. Klein. Bethlehem, Pa.

We have received from the head of this department a pamphlet descriptive of the course and methods of study pursued in the School of Mechanical Engineering. From an examination of this circular—which gives much fuller details as to the kind of work done and the methods of instruction than one is accustomed to find in a college publication—it would appear that, in respect of both, this progressive institution affords exceptionally good facilities for students ambitious to qualify themselves for the profession of the mechanical engineer. The course appears to combine, in a judicious manner, theory with practice; and the location of the University, at South Bethlehem, Pa., in the midst of a number of the largest industrial establishments

in the country, to which the students have free access for observation and study, is an advantage which will be duly appreciated.

The technological courses of the Lehigh University embrace the following departments: (1) Civil Engineering; (2) Mechanical Engineering; (3) Mining Engineering and Metallurgy; (4) Electrical Engineering; (5) Analytical Chemistry; (6) Architecture. The pamphlet of the Mechanical Engineering course, here referred to, is the first of a series, which will be followed by similar publications descriptive of the other departments. W.

Practical Work on General Physics, for use in schools and colleges. By W. G. Woolcombe, M.A., B.Sc., etc. Printed at the Clarendon Press. New York: Macmillan & Co. 1894. Price, 75 cents.

This work is designed as a manual for the student to familiarise him with the apparatus and methods of experimental work. There has been a radical change within the past decade or two in the methods of instruction in science, growing out of the better appreciation of the fact, that experimental work must go hand-in-hand with book or lecture instruction if the student is to reap the full benefit of his scientific studies. The present book is one of a number of such practical guides to experimental work, which have been prepared in answer to the needs of schools where physical science is taught. It is well arranged for its intended purpose, and will be found useful where a graded course of elementary physical experimentation is desired. W.

Quarterly Digest of Physical Tests and Laboratory Practice. A *résumé* of practical tests made in the laboratories of the world. Philadelphia: Riehlé Bros. Testing Machine Company, Proprietors and Publishers. Vol. I., January, 1896, No. 1. Price, $1 per year. Single numbers, 30 cents.

This periodical, of which the initial impression has just appeared, is designed to cover a field which has not yet been exclusively appropriated by any other technical publication in this country. If it shall adequately meet the possibilities of its title it will prove of the greatest service to the engineering profession. The contents of the first impression embrace a number of original contributions by well-known writers, and numerous useful abstracts. The new journal appears in magazine form, an 8vo of 86 pages, well printed and liberally illustrated. W.

The Elementary Principles of Mechanics. Vol. I, Kinematics. By A. Jay DuBois, C.E., Ph.D. New York: John Wiley & Sons, 1894. Pp. x, 231.

This work is the first of a series, the other two being called Statics and Kinetics. This first volume is divided into four general divisions: an Introduction of 14 pages; the General Principles of Kinematics, 76 pages; Kinematics of a Point, 78 pages; and Kinematics of a Rigid System, 63 pages. In the body of the work a difference in type enables one to separate what might constitute an abridged course from articles intended for advanced students, while those articles containing applications of the calculus are enclosed in brackets.

It is doubtful whether a work of this kind is of any value to students who

are not fairly familiar with the principles of calculus. The number of formulæ, some of them quite intricate, which are expected to be handled in the abridged portion of the work would seem to indicate that a high grade of mathematical knowledge should be possessed by the student before beginning the subject. In a subject as important as the one here treated of the calculus preparation should always be required if the matter is to be properly presented in the time which should be allotted to it in an engineering course.

The "Introduction" covers the definition of the units the author intends using, and what are called dimensional equations, together with definitions of such terms as "rigid system," "motion of translation," etc.

The part treating of "General Principles" is subdivided into speed, rate of change of speed, displacement, velocity, acceleration, moments, angular revolution and differential equations. It is interesting to note the continual use of dimensional equations, which have no more to do with mechanics than with any other exact science, and which add to the learned look of the printed page without, in the slightest, adding to the clearness.

The author continues the physicist's contention, that it is desirable to make sufficient distinction between speed and velocity, to repeat the same equations and almost exactly the same wording while dealing with each. It is easy to understand that the difference he makes he considers essential; but on page 43 he states that "it follows that the unit of velocity is the same as the unit of speed;" and on page 51, "all of the equations are precisely similar to those on page 28, except that we have f in place of a;" "these," referring to equations of motion in the chapter on acceleration, and "those," to similar equations in the chapter on rate of change of speed.

It is interesting to note that the use of the term "speed" as the unit of velocity is marked (Rare) in the Standard Dictionary, and it is to be hoped that it will soon be marked (Obs).

That portion of the work treating of "Kinematics of a Point" is subdivided into rectilinear motion, translation in a curved path, and constrained motion.

The ground is covered completely, using freely the calculus, and in many instances dropping away from the mathematical formulæ, and deducing the results desired by a clear course of reasoning which is very satisfactory. There is one problem which is sure to attract any one casually looking over the book. It is a selection from "Hiawatha," where his fleetness of foot is extolled, and the author supposing that an arrow is shot every second, aimed so that its range is greatest, concludes that about 99 miles per hour was his speed.

The last section of the text is subdivided into rotation, translation and rotation, and a general analytic analysis of a rigid rotating system.

Chapter I treats of rigid system with one point fixed, and seems to be entirely unnecessary, and the entire chapter could be replaced by a single paragraph, showing that what has already been proved relating to the movement of one point about another fixed point, exactly covers all the conditions which might be imposed on the rigid system here, discussed.

Chapter II treats generally of combination of non-concurring angular

velocities, and the special case of rotation and rectilinear translation combined. The treatment is satisfactory from a mathematical standpoint, but an examination of the problems at the end of the section shows that the greater part of them could have been solved with only a common-sense application of the elementary ideas on which the chapter is founded. One of the very good features of the book is the large number of examples at the end of each subdivision of the subject. One of the unfortunate things is that a comparatively few pages would cover all the knowledge of mechanics, and a little common-sense and few intricate mathematical formulæ would be sufficient to apply the little knowledge of mathematics to the successful solution of most of them.

H. W. S.

Franklin Institute.

[*Proceedings of the stated meeting, held Wednesday, February 19, 1896.*]

HALL OF THE FRANKLIN INSTITUTE,
PHILADELPHIA, February 19, 1896.

MR. JOSEPH M. WILSON, President, in the chair.

Present, about 400 members and visitors.

Additions to membership since last report 12.

The Board of Managers, to which had been referred the question of permitting members to vote at the annual election by letter-ballot, reported that it was inexpedient to make the change proposed.

Drs. Edwin J. Houston and A. E. Kennelly presented a joint paper entitled "A Communication Concerning the Röntgen Rays." The paper was a historical *résumé* of the subject, with critical considerations respecting the recent developments of Röntgen's investigation. The authors illustrated their paper by the exhibition of the apparatus employed in photography with the X rays, and of a large number of prints and lantern slides of such photographs.

The discussion of the paper was opened by Dr. Kennelly, who was followed by Prof. A. E. Dolbear, Prof. Elihu Thomson, Dr. Jos. W. Richards, Prof. Charles F. Himes, Prof. Geo. A. Hoagley, Mr. W. N. Jennings, Mr. John Carbutt, Mr. James Wilson, Mr. A. E. Outerbridge, Jr., Prof. M. B. Snyder, Mr. Charles Richardson, Mr. E. G. Willyoung, Prof. L. F. Rondinella, Prof. Geo. F. Stradling, and others. The discussion was closed by Dr. Kennelly, who moved that the thanks of the Franklin Institute be transmitted to Prof. Dr. Röntgen, of Wurzberg, for his important contribution to science in investigating the properties of the X rays. The motion was numerously seconded, and, on being put to vote, was unanimously adopted.

The paper of Drs. Houston and Kennelly, with the discussion thereon, will be printed in the *Journal*.

Adjourned.

WM. H. WAHL, *Secretary*.